DISCOVERY

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OUR COVER PICTURE

The surface of a diamond as seen with multiple-beam interferometry.

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SCIENTIFIC FREEDOM IN THE SOVIET UNION

The scientific community in the Soviet Union has finally got around to rapping the knuckles of the Soviet scientist who explained a number of mysteries by assuming that a giant spaceship visited the earth in the remote past.

The widely publicised theory appeared in the *Literaturnaya Gazeta* early last year. Its author, A. Agrest, a physicist and mathematician, said that the huge Baalbeck terrace, a vast and unexplained platform of huge stone slabs near the Libyan Desert, might have been the launching platform for a spaceship or a structure built by space travellers to commemorate their visit to the earth. He built up his case by stating that the glassy tektites found in the area were the product of extremely high temperatures and radiation and said they might have come from rocket probes that were sent to the earth and burned up in the earth's atmosphere. As further evidence, Agrest pointed out that the Dead Sea scrolls found in the area of the Anti Lebanon Mountains contained a description of the destruction of Sodom and Gomorrah which could be regarded as an account of a nuclear explosion which might have taken place when the space travellers had destroyed their surplus stocks of nuclear fuel after warning the local population in advance.

Adding layer upon layer to the already towering monument to science fiction, he went on to state: "Historians have so far been unable to trace Ivan the Terrible's library. We would like to ask: Can it be that certain non-terrestrial bibliophiles, learning of this immensely rich collection of books, spirited away the ancient volumes into outer space?"

Since the article must have had some official sanction, Soviet scientists were reluctant to criticise it publicly until they knew where they stood. It was not until the better part of a year had passed that any criticism appeared. When it finally did come, it was official and collective. The timing and manner were a remarkable demonstration of "scientific freedom". The criticism came in a resolution adopted at a meeting of the Academy of Sciences which condemned Agrest's hypothesis as "anti-scientific and therefore harmful". Once the official line was established, the pendulum went over to the other extreme and there was a torrent of abusive criticism that is equally alien to the general approach of scientists to such matters.

"Such a monstrous idea as Agrest's 'hypothesis' could only come from a person ignorant both of technique and history," was part of a statement issued by Prof. V. V. Pavlov, an Egyptologist.

Taking their cue from the title of Agrest's original article which was "Do The Traces Point To Outer Space?", two Soviet engineers writing in *Komsomolskaya Pravda* said, "The traces point not to outer space but to ignorance. . . . Agrest's 'hypothesis' is harmful because it diverts our youth from a desire to study seriously and investigate the 'blank spots' in present day science—the unsolved mysteries of nature."

This situation could never have arisen in those parts of the world where scientists are free. Such a theory would never have received such widespread notice in the first place, and, secondly, it would have been immediately discredited and dismissed by the scientific community with hardly a ripple. Crackpot theories on almost every subject come and go with monotonous regularity.

The strides made in science everywhere—no less in the Soviet Union—have been directly proportional to the freedom of its practitioners to assert and dispute without waiting for the official position. This incident in the Soviet Union indicates that fear of the State still takes precedence over the regard for honesty and integrity. R. K. M.

THE PROGRESS OF SCIENCE

NEW MEANS OF HARNESSING NATURAL RESOURCES

In the harnessing of water power, the newest and most practical development of recent years is the reversible pump-turbine.

These units will operate with as little as a 12-ft. drop, and this feature combined with their relative cheapness and the simple civil engineering structures that are required, may well lead to the harnessing of many watercourses now considered uneconomic or unfeasible in the technical sense. One outstanding project under way utilises the stretch of 240 miles of the Lower Vistula, from Warsaw to the sea. The fall over the whole distance is only 870 ft., but nine power stations with a total generating capacity of 1,120,000 kW are being considered. When cheap off-peak energy is available from the system it will pay to draw water upwards from the sea to the higher dam-reservoirs for the generation of the extra power needed during the peak load periods.

A fascinating way of putting the sun to work is being developed in both Egypt and Spain. The Egyptian scheme for using the Quattara Depression as a gigantic evaporating pan is not new but it has recently been entirely re-studied. The plan is to pipe water from the Mediterranean over a distance of 43 miles to a depression 150 miles west of Cairo which, at its lowest point, is 440 ft. below sea-level. At 165 ft. below sea-level its area is 5200 sq. miles. Details are shown below and on the oposite page.

The sea-water would pour into the depression through a power station of 600,000-kW capacity and then disappear by evaporation. The scheme would provide valuable chemical by-products as well as irrigation water for the Western Desert. It may be economically profitable after the Nile High Dam project has reached the stage where all its energy is employed.

The Spanish scheme involves the Sebja Tah, in the Western Sahara. Here an evaporating surface of 58 sq. miles at a level of 170 ft. below the sea would provide between 26,000 million and 33,000 million units of electricity a year, as well as large amounts of salt. The scheme has the advantage of needing an intake from the sea of only 7·7 miles in length, all in tunnel form. It could provide 8,400,000 tons of salt a year, giving 4,590,000 tons of chlorine, 75,000 tons of bromine, 2,530,000 tons of sodium, and 183,000 tons of magnesium which up to now has had to be imported from the United States.

The electrical generating capacity of all the water power units in the world is estimated to be about 121 million kW. Thermal power units produce about 233 million kW, giving a total of 354 million kW, according to the International Bank for Reconstruction and Development.

THE CRAB'S CLOCK

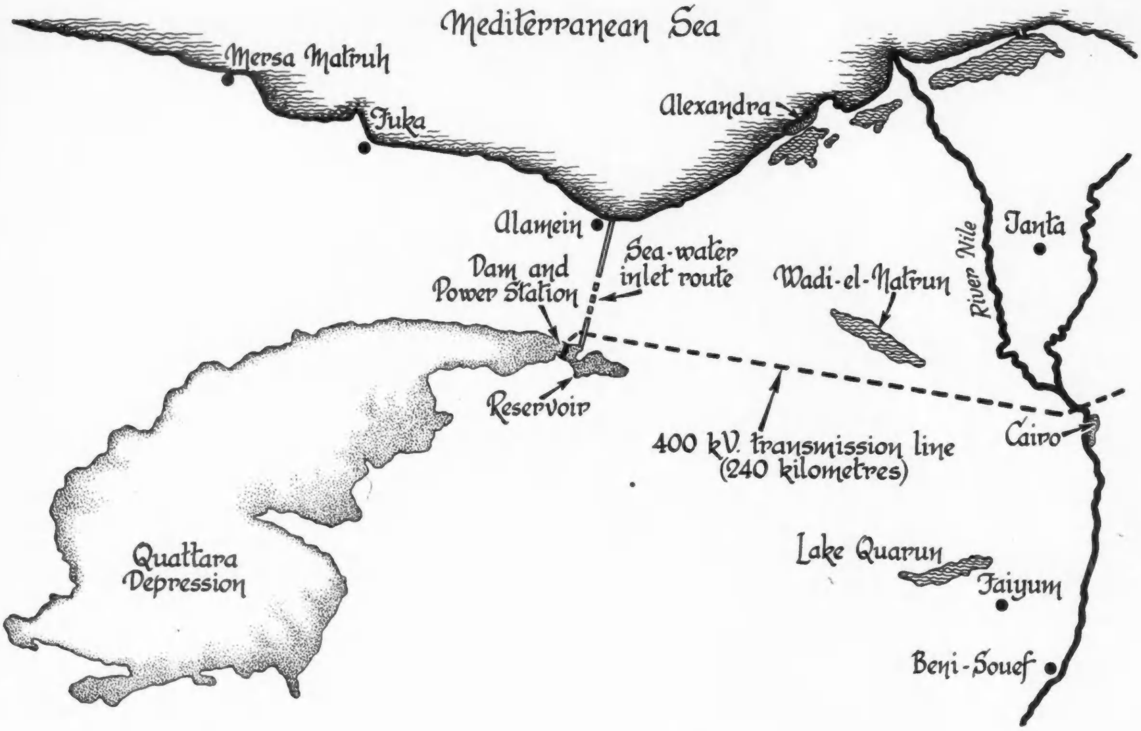
Recent research suggests that the rhythmic behaviour of many marine creatures is not directly due, as might be supposed, to the influence of such obvious external rhythms as the tide and the day-and-night pattern produced by the earth's rotation. It seems to be due, rather, to the action of internal "clocks". These are usually in phase with one or more of the environmental rhythms but the "clocks" continue to work when the environmental stimuli are not present, so there is no simple cause and effect relationship.

The rhythms of crabs have been studied in some detail by Dr E. Naylor of the University College of Swansea. Common green seashore crabs move about the beach when the tide covers them but remain still and out of sight when the tide goes out and the shore is exposed. When removed to the laboratory, where they are kept in a constant temperature room which is continuously lit by a dim red light, however, they continue to show the same regular bursts of activity followed by periods of quiescence that characterised their seashore behaviour.

There appear to be two separate cycles. Some bursts of activity occur about every twelve and a half hours, coinciding with the high tide on the shore from which the crabs were collected. Other bursts coincide with the hours of darkness. When high tide occurs at night, the activity reaches a maximum. Interestingly, the same tidal rhythm was found in crabs of the same species which were found in docks not affected by tides, pointing to the possibility that this behaviour might be inherited. Similar inherited rhythms are known in some non-marine creatures.

How do the "clocks" of animals work and in which parts of their bodies are they located? Since they are often in-

Schematic diagram of the Egyptian project which will utilise the Quattara Depression for the generation of electric power. (*Opposite page*) Map of area showing location of project.



dependent of temperature changes, it is unlikely they are controlled by simple biochemical processes. In crabs, there is some evidence that the sinus gland in the eyestalk may have an important effect on the rhythm and this possibility is being investigated further. Attempts to learn more about the phenomenon will also be made by subjecting crabs to cyclical changes of light and tide which are different from those they would normally experience. If internal timing mechanisms are widespread in marine animals, they may help explain such things as the semi-lunar spawning periodicity of oysters and other shellfish, and the precisely timed annual spawning of the palolo worm.

LOW-LEVEL RADIATION AFFECTS SEIZURES IN MICE

Evidence that extremely small amounts of radiation, including that from atomic fallout, can profoundly affect the neural functions of mammals was presented at a recent symposium in Chicago on the nervous system's response to radiation. Even the low levels associated with background radiation must be re-examined in the light of new findings by Dr D. S. Miller of the University of Chicago that were reported in *Medical News*.

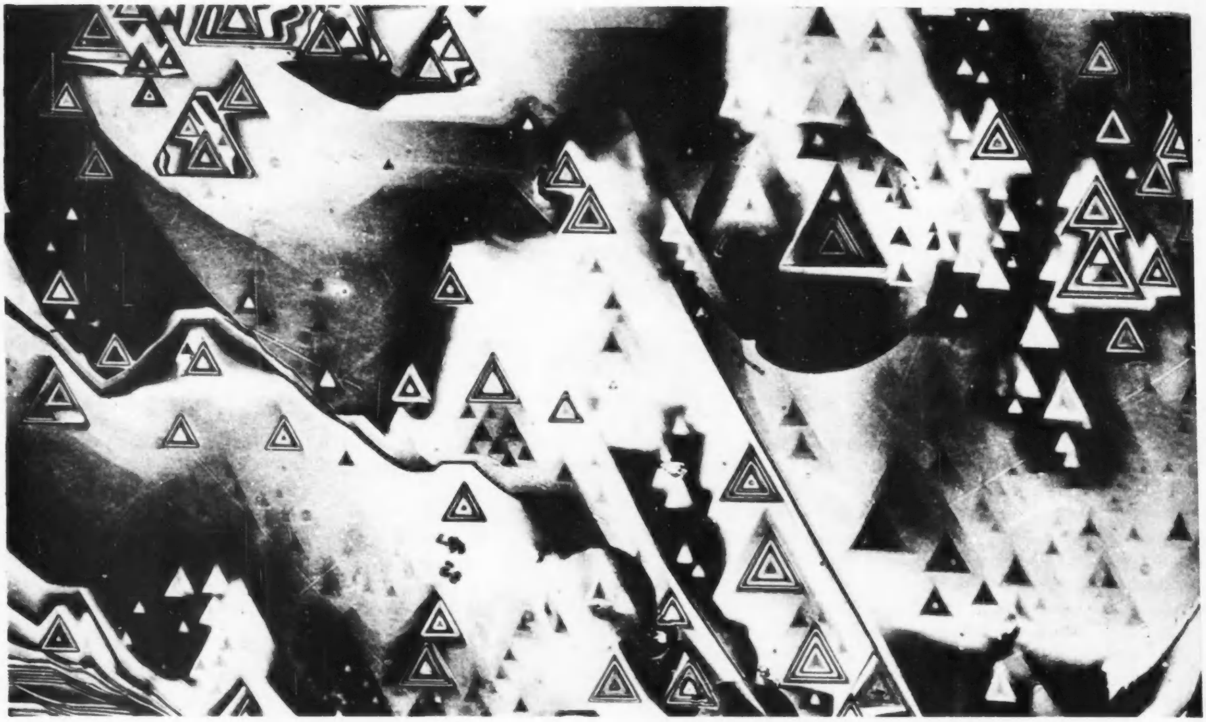
Dr Miller states that doses as low as 0·15 röntgens influenced the susceptibility of certain strains of mice to audiogenic seizures, physiologically and genetically. In most parts of the world, the background radiation is between 0·05 and 0·15 r. per year.

The effect of low-level radiation was discovered by sheer chance during experiments that were being conducted on seizure susceptibility by crossing seizure-susceptible mice with non-susceptible lines. Shortly after a predictable incidence of seizures had been established for various groups, the animal colony was moved to another laboratory. There was an immediate unexplainable increase in seizure frequency in all groups, the proportion of fatal seizures also increasing. A careful check failed to uncover any change in food, background sound level, personnel, or other factors that might have affected the animals' behaviour. When a second mutation (in coat colour) appeared in the colony, the mouse quarters were checked for radiation. A level of 0·1 to 0·2 millirads per hour (five to ten times the normal background) was traced to a cobalt-60 unit in a nearby laboratory which was unshielded on the side facing windows of the animal quarters. During the thirty-day period before seizure-susceptibility testing, the mice had received 0·15 r. it was found. When the animals were moved to new quarters, seizures at once became less frequent.

It was clear at the same time that the radiation dose from the cobalt-60 source had exerted a genetic as well as a direct environmental effect. The progeny of one line of seizure-susceptible mice, born after the parents had been moved to a radiation-free environment, displayed less susceptibility than that established for the breed and the incidence of fatal seizures dropped from 96% to 49%. Radiation had the opposite genetic effect on a line of seizure resistant mice, resulting in an increase of seizure frequency.

A controlled experiment confirmed the link between low-level radiation and seizure susceptibility but this was followed by another unexpected and striking increase in seizures. This time, the possibility of extraneous radiation was promptly checked and it was found that the rise coincided exactly with a sharp increase in the fallout level. The first litters showing an unusual sensitivity to sound were born at about the time the Atomic Energy Commission showed an eighty-fold increase in background beta and gamma radiation. Fallout levels throughout the summer of 1959, when the tests were being run, were closely reflected in seizure frequency and severity, according to Dr Miller, and the youngest mice were found to be the most sensitive.

continued on page 41



A NEW LOOK AT SOME SURFACES WITH MULTIPLE-BEAM INTERFEROMETRY

Part I

S. TOLANSKY

By making it possible to look at surfaces with a vertical magnification of millions, this technique is throwing new light on such widely diverse phenomena as patterns of crystal growth, the wear of glass-cutting diamonds, and the surface distortion from hardness tests and high-speed impacts.

Since its initial establishment some seventeen years ago, the technique of multiple-beam interferometry has made considerable progress and now has wide application (see references). The purpose of this article is to illustrate briefly its range of possibilities. Apart from the purely academic optical applications, of which there are several, the variety of multiple-beam techniques developed have been found extremely useful in the study of surfaces and thin films. The photographs shown here were taken during some of my studies in this field.

S. Tolansky, F.R.S., D.Sc., Ph.D., is Professor of Physics at Royal Holloway College, London University.

The examination of the flatness and perfection of surfaces by optical interferometry goes back almost eighty years to Laurent but the first one to apply such methods on a microscopic scale to crystals was Siegbahn in 1932. These earlier experimenters used two-beam interferometry, matching the surface under examination against an optical flat, with a slight angle of inclination between the surfaces.

In such a technique, the reflected light from the object interacts with the reflected light from the glass reference flat placed over it. If the two reflected waves are in phase, they will reinforce each other; if they are out of phase, they will cancel each other out. Whether they reinforce or cancel each other out at any given point depends on the spacing between the two surfaces but it is quite apparent that a series of light and dark bands will result. It was Laurent who first pointed out that such localised interference fringes effectively constitute a true optical contour map. Each fringe represents a height change of half a light wave—some 2500 Å or about 1/100,000th of an inch. The width of the fringe limits reasonable analysis to something like a fifth of a fringe width or 500 Å but much valuable work can be carried out with this technique nevertheless, and, in special cases, the

FIG. 1 (*left*). Surface of a diamond as seen with multiple beam interferometry. Horizontal magnification: 85×.

accuracy can be pushed appreciably further.

Fig. 2 shows Newton's rings—the familiar two-beam fringes produced when a lens is placed on a glass flat. Fig. 3, however, shows the marked change in appearance which arises when one uses what is called a "multiple-beam technique." The broad fringes have become fine narrow lines and more correspondingly sensitive measurements are now possible.

The multiple-beam effect is produced by coating both the reference flat and the surface to be examined with a highly reflecting layer of silver or a complex of dielectric materials.

The thickness and purity of both layers are highly critical. They must have a high reflectivity (at least 95%), as low an absorption as possible (certainly less than 4% and preferably much less), and must transmit at least 1%. It is also important that the silver layer on the surface to be examined "contours" the surface structure very faithfully, even down to molecular dimensions. With care, these conditions can be satisfied with a silver film some 700 Å thick, or in that order. If the

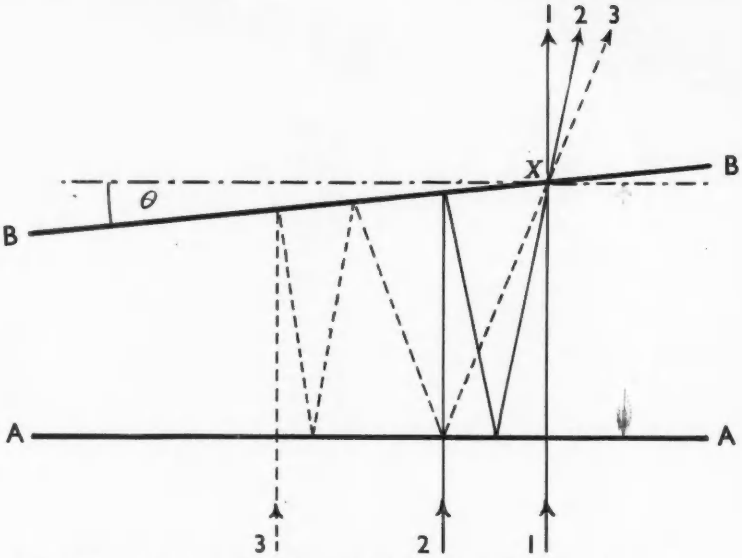


FIG. 4. Schematic diagram showing principle of multiple-beam interference.

reflectivity is high, the fall-off in intensity of successively reflected beams may be so slow that sixty or even eighty beams may make a significant contribution to the total intensity at a given point.

To obtain the desired effect, it is crucial that the two surfaces be extremely close together—a few light waves apart at most, preferably less. Then, and only then, will the beams combine in a manner that will produce the sharp fringes of multiple-beam interferometry. This key point was missed by early investigators.

TRANSPARENT AND OPAQUE SURFACES

When the object under study is transparent, light can be sent through *both* the silvered object and the silvered reference flat, producing *transmission* fringes which are bright narrow lines on a broad dark background. When the object under study is opaque, light is sent through the flat and reflects back to produce *reflection* fringes which are fine dark lines on a broad bright background.

The way in which multiple beams build up locally to form transmission

FIG. 2. Newton's rings—two-beam interferometric pattern. Horizontal mag. 10×.

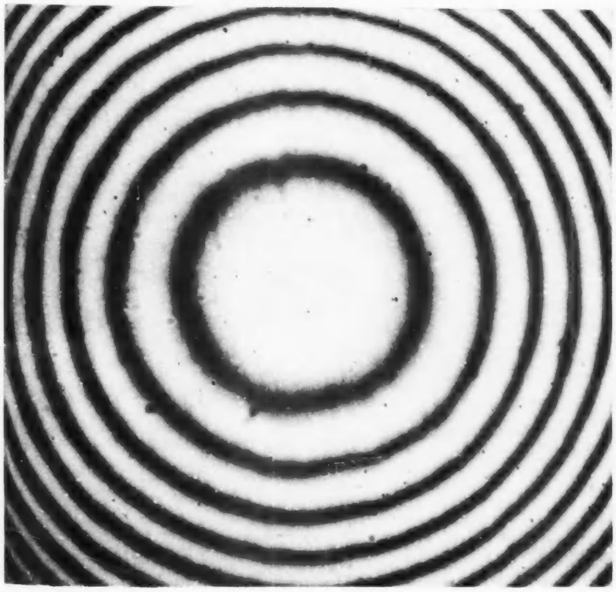
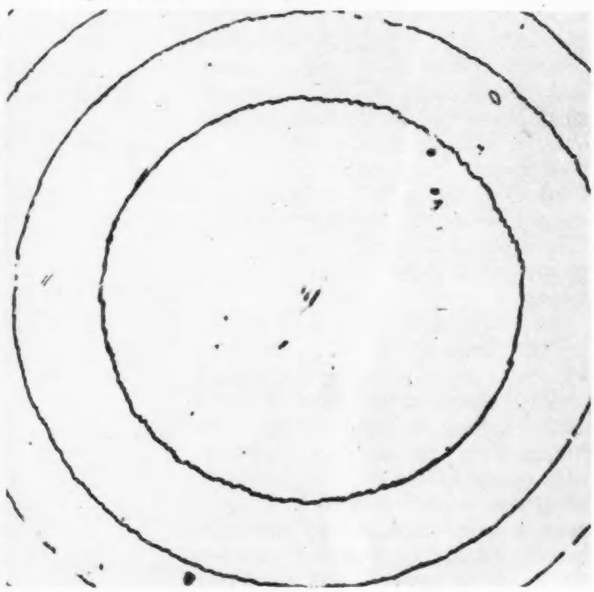


FIG. 3. Newton's rings—multiple-beam interference pattern. Horizontal mag. 10×.



fringes is illustrated in Fig. 4. A and B are two highly silvered surfaces inclined at a small angle θ. Ray 1 meets B at x. Ray 2 also meets B at x after two reflections and Ray 3 meets at x after four reflections. This goes on for up to 60 rays, even 80 or possibly 100. If the surfaces A and B are very close together, all these reflections take place over a small topographical feature, indeed over a region comparable with the resolving power of a microscope.

With the right technique, fringes having an astonishing degree of sharpness can be produced. Indeed, it is not too extreme to claim that one can secure magnifications and resolutions exceeding that of the costliest electron microscopes with nothing more than a crude piece of glass that is correctly silvered and properly used. But—and this is a warning—interferometric magnification is in one dimension only—up and down. On an interferogram, the magnification *along* the surface will be that of an ordinary optical microscope; in the *up-down* direction, magnifications of 1,000,000 and resolutions of 10 Å will be possible. Let us now look at some multiple-beam interferograms with an increasing degree of complexity.

PERCUSSION MARKS ON DIAMONDS

In our studies on the strength of diamond, we have found that it is easy to initiate hexagonal-shaped percussion marks on the octagonal faces of diamonds by applying either diamond or tungsten carbide balls under surprisingly small loads. Fig. 5 shows the small hexagonal crack produced when a 1-mm. tungsten carbide ball under a load of only 20 kg. was applied to the octahedral face of a diamond. The damage around the crack appears great; a multiple-beam interferogram reveals a remarkably slight amount of *surface* damage.

An interferogram with fringes crossing the percussion mark is shown in Fig. 6. It is noteworthy for several reasons but one's attention is first drawn to the striking sharpness of the three fringes. They are only about 2/3 mm. wide (about 1/67th of the separation). The fringe width represents a displacement of some 40 Å. As we have adequately established that it is possible to detect and measure a displacement

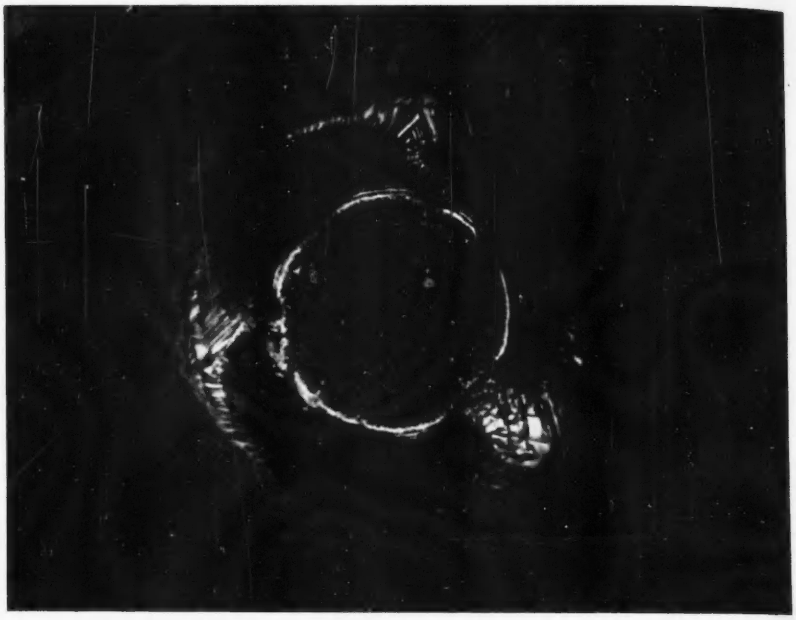
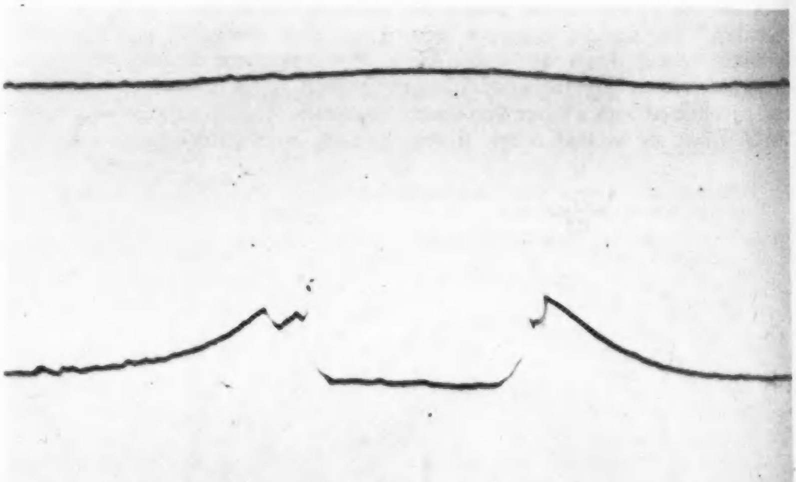


FIG. 5 (*above*). Ring crack on a diamond crystal face produced by a 1 mm. tungsten carbide ball under a 20 kg. load. Horizontal mag. 240×.

FIG. 6 (*below*). Interferogram of ring crack.



of only 1/5th of a fringe width, a mere 8 Å displacement can be resolved on the surface shown in Fig. 6.

In this picture, the magnification in height is no less than 165,000 and it can be made much greater if necessary. It is always well to remember, however, that there is always a large ratio between vertical and horizontal magnification in interferograms. The ratio in Fig. 6 is some 700 : 1.

It is evident that we have here a very powerful weapon for investigating surface micro-structure. For example, Fig. 6 shows that this particular hexagonal percussion mark has a flat base inside the crack that is essentially undisplaced from its original position, whilst outside the crack the surface has piled up to a height of some 800 Å.

It is important that the feature to be examined extend across the surface over a region that is readily resolvable by an optical microscope. Areas down to 1/100th mm. in diameter are amenable to examination by precision interferometry.

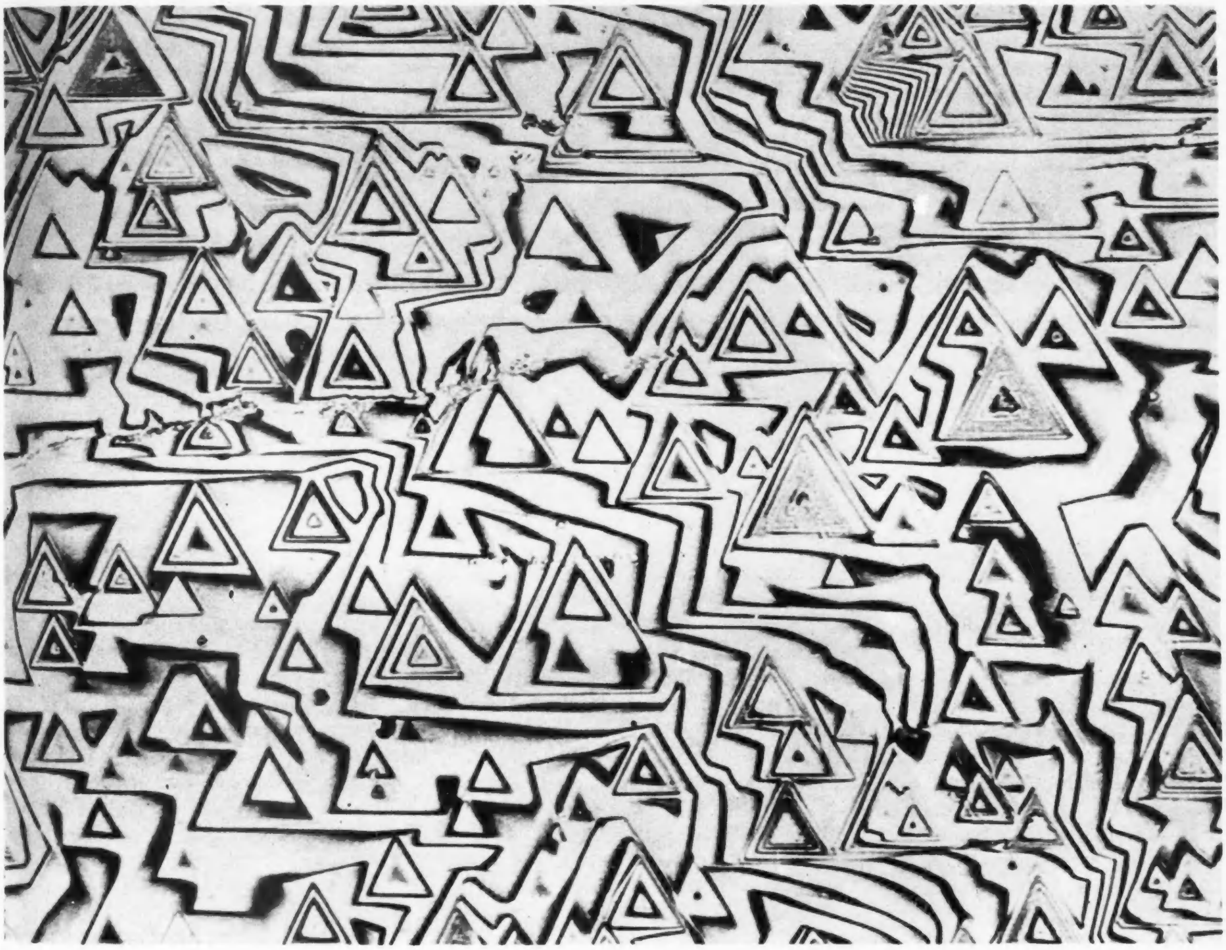
Multiple-beam interferometry has made some striking contributions to the exploration of the microtopographical structures of crystal faces. With its aid, a really three-dimensional microscopy has emerged. It will suffice to select a few examples but before proceeding to review these, one basic item of technique will first be considered.

It has already been stated that surface features with heights in the order of 10 Å can be resolved and measured. To produce multiple-beam interference patterns, however, it is necessary to evaporate on to the surface under study a silver film with a thickness of 700 Å—seventy times as thick as the resolving limit claimed. The question which immediately arises is whether a 700 Å thick silver film can faithfully contour a much shallower structure. If we have a step 10 Å in height and evaporate on to this a 700 Å layer of silver, will the step reappear on top of the silver film? The answer is yes and we have proved it with a multiplicity of independent methods. There is no doubt that the contouring is faithful down to molecular dimensions.

DIAMOND SURFACES REVEAL GROWTH MECHANISM

Let us now go on to some of the fascinating fringe patterns given by different crystals, beginning with the

FIG. 7. Interferogram of diamond surface showing small equiangular depressions called *trigons*. Horizontal mag. 55×.



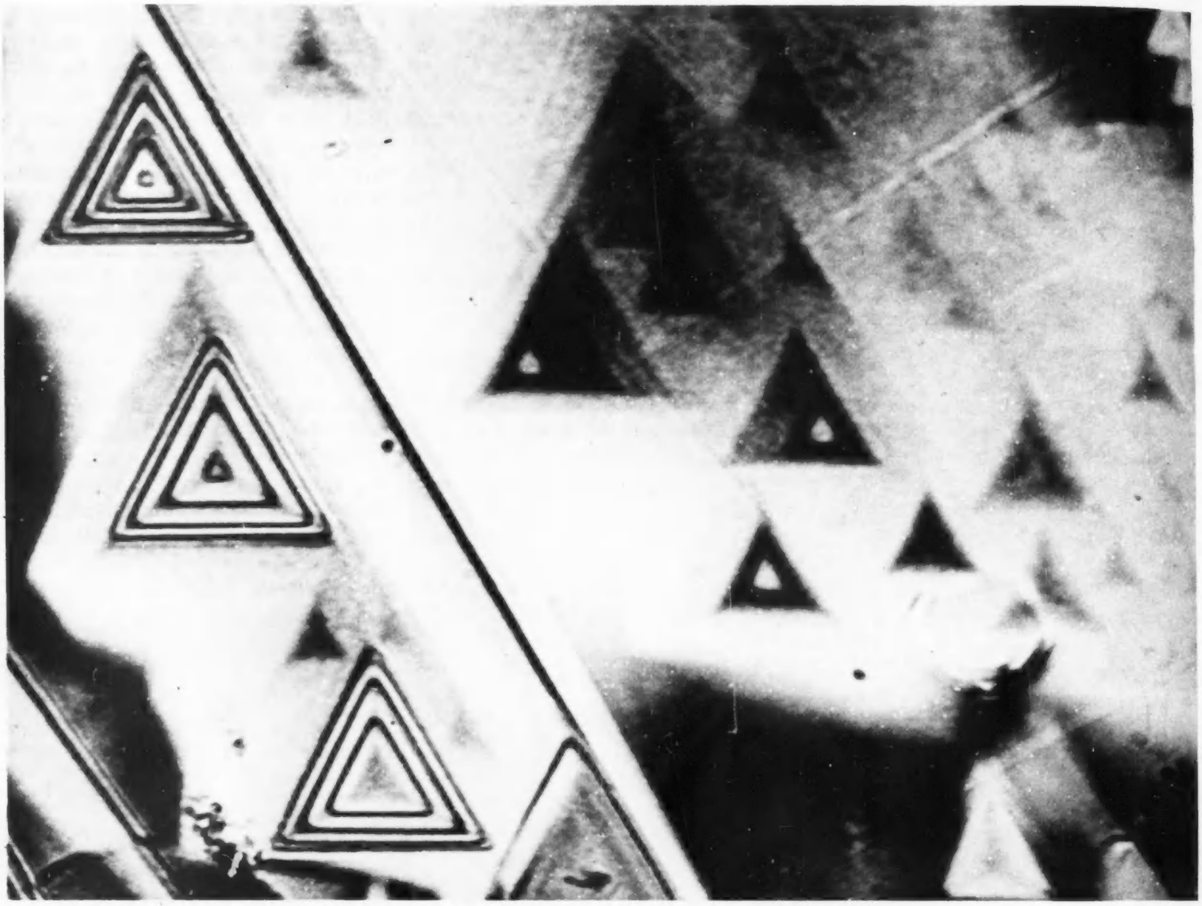


FIG. 8. Interferogram of diamond trigons showing *interference contrast*. Horizontal mag. 200×.

diamond. Perhaps half of the diamonds that are mined are of partial or complete octahedral habit and on innumerable octahedron faces (probably on all) small equiangular triangular depressions appear which have been named *trigons*. There has been a great deal of controversy extending over half a century as to whether these are due to growth or etch. We are of the opinion that interferometry has settled this controversy in favour of growth. Some trigon patterns lead to striking interferograms, such as the one of Fig. 7—a bewildering array indeed. A closer look at a trigon region on another crystal, Fig. 8, shows how powerful this technique is. Apart from the data one can obtain from the fringe pattern by means of precise measurements, much useful information can be secured merely by inspection.

In this picture, there are two distinct types of trigons—the larger and deeper group to the left and the smaller and shallower group to the right. Consider, first, the trigons on the left. The depth can be estimated merely by counting the fringes within any trigon. Furthermore, it is quite obvious at a glance that two of the trigons are pyramidal, and the third is a truncated pyramid. Fringes within a trigon that are equally spaced indicate that the descending wall must be flat. In the middle trigon of the group, the fringes are not equally spaced, showing clearly that the walls are curved.

The small uniformly tinted trigons to the right of the picture are very shallow features that illustrate what can be called "interference contrast", an optical feature at least as sensitive as phase contrast but, in fact, complementary to the latter in an interesting way. Multiple-beam interference, when produced between almost parallel surfaces, results in strong alterations in contrast with slight changes in height. The changes in intensity are so sensitive to height alterations, in fact, that a recognisable 10% change is produced by a height change of only $2\frac{1}{2}$ Å. This system thus offers a highly sensitive method for revealing very shallow surface features.

The use to which it can be put can be illustrated by considering the mica crystal which has a lattice spacing between cleavage planes of 20 Å. A step of but *one single* cleavage lattice spacing would produce a 50% change in intensity in the interferogram. The shallow trigons in the right half of Fig. 8 are perhaps only a few lattice spacings in depth. Shallow trigons can also be seen in Fig. 1 and in the picture on the cover.

An extensive study of many hundreds

of diamonds has shown that numerous octahedron faces (perhaps all) are covered with a multitude of shallow trigons. Fig. 9 is an instructive interferogram taken on a diamond octahedron face which shows how basic information can be secured from the character of a single fringe. The two surfaces—that of the diamond and that of the reference flat—have been set at a very small angle making the dispersion so high that the fringes spread out and only one broad fringe crosses the field of view. Since the width of the fringe relative to the separation between fringes remains the same (about 1 : 55 in this case), the width still corresponds to a height (depth) change of some 50 Å, but there are now indents in the fringe from the shallow trigons. Since many have a depth of no more than one-fifth of a fringe width, we can conclude that there are numerous trigons on the surface with depths of the order of 10 Å or even less. One sees, in fact, the whole growth mechanism of the diamond clearly revealed.

The growth of a diamond crystal can be postulated as plane-sheet growth along three planes that are equally inclined to each other—a reasonable crystallographic hypothesis. This would lead to the production of equiangular pits that fill in as the crystal grows and leave the kind of surface pattern we see on an interferogram.

INTERFERENCE VERSUS PHASE CONTRAST

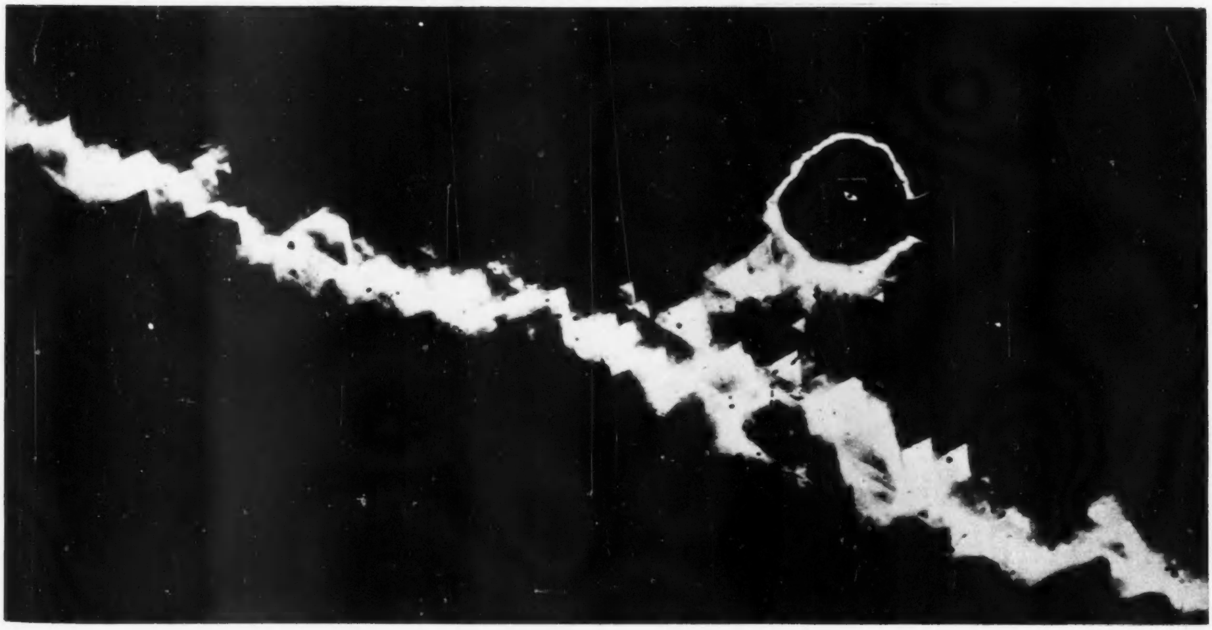
Attention may be drawn at this point to an interesting optical difference between the Zernike phase-contrast technique and interference-contrast. Phase contrast operates essentially through diffraction. It is therefore very effective for revealing edges and boundaries which act as diffracting edges but it is not so effective over the areas in between, since differences in height are not effectively rendered as differences in contrast. Furthermore, the system works at its best with high-power lenses that are used to examine small diffracting features.

Interference contrast, on the other hand, shows intensity differences in adjacent areas when the areas are at only slightly different levels. It is therefore equally effective at both low and high magnifications and, indeed, can be used to produce macro-pictures with unit magnification.

NEW LIGHT ON SPIRAL CRYSTAL GROWTH

Multiple-beam interferometry has made striking contributions to the work on spiral dislocation theories of crystal growth; it has indeed to our study of silicon carbide crystals. These crystals frequently show beautiful spiral growth patterns like the one in Fig. 10, which was taken with a good phase-contrast microscope. Fig. 11 shows the type of interferogram we can obtain from such spirals. Here the fringe pattern has been carefully placed so that one fringe runs right across the peak of the spiral ramp. It contains a considerable amount of information, showing, for instance, that the spiral ramp has a small but remarkably uniform "stair" height. We find that the height of these spirals are usually small integral multiples of the crystal lattice spacing. The steps in this case are 165 Å high—exactly eleven times the lattice spacing. Equally noteworthy is the smooth perfection of the surfaces between the spiral edges. In regions where the fringe runs along the surface of the ramp for a considerable length between steps, it is apparent from its straight smooth character that the surface is molecularly flat and smooth *to within a single lattice spacing*. It will be noticed, also, that the fringe pattern across the peak curves upwards slightly. This is not because the step height changes but, rather, because the width between the step ledges increases

FIG. 9. Single fringe of interference pattern across diamond surface, revealing multitude of shallow trigons. Horizontal mag. 300×. Depth of trigons: 1/25,000,000th of an inch.



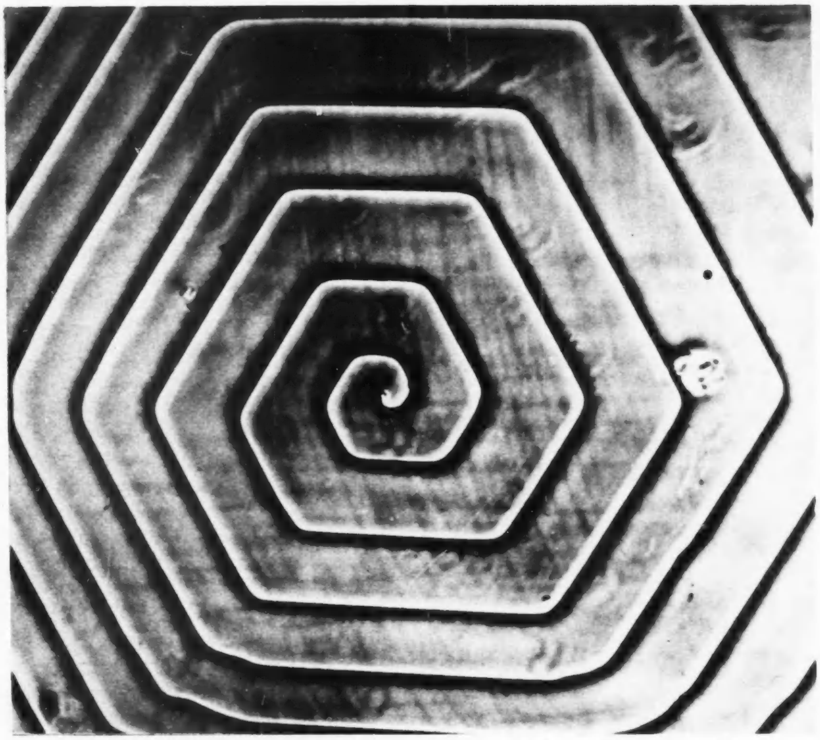


FIG. 10 (*above*). Spiral growth pattern on silicon carbide crystal as seen with a phase-contrast microscope. Mag. 230×.

FIG. 11 (*below*). Spiral growth pattern on silicon carbide crystal as seen with multiple-beam interferometry. Horizontal mag. 100×.

progressively from the centre outwards. The step height itself remains uniform throughout the development of the spiral pattern from the centre to the edge, as the fringe pattern shows.

On some crystals—depending on the possibility of a close approach between the interference surfaces—we have been able to secure phenomenally fine definition. Fig. 12 is an example. An interferogram that is as sharply defined as this one yields very precise numerical data. From Fig. 12 a step height of 15·2 Å was derived; the true lattice spacing for this particular polymorphic variety of silicon carbide, as given by X-ray analysis, is 15·08 Å. This demonstrates the real power of multiple-beam interferometry, for it is quite an achievement to measure crystal lattice spacings, even approximately, by means of visible light waves. To be so close to the true value is an indirect confirmation of the complete validity and reliability of the whole interferometric approach to the study of topography.

SOME STUDIES OF SURFACE DISTORTIONS

A fruitful field of application for this technique has been the study of the distortions appearing on metal surfaces which have been subjected to indentation or to machine working. It is standard practice in metallurgy and engineering to use indentation tests to measure the hardness of the metal. A variety are in use and one of them—the Vickers Diamond Hardness test (VDH)—will be employed here to show how interferometry can produce useful information about the indenting mechanism. In the VDH test, a carefully shaped square-based diamond is pressed into the metal under a known load which may vary from 5 gm. in a microtest to perhaps 50 kg. in a macrotest. Plastic deformation occurs and the hardness of the material is computed from the dimensions of the indentation left in it. According to British Standards specifications, a new test indentation should be separated from a previous one by at least $2\frac{1}{2}$ times the diagonal of the indentation to avoid being affected by it. We have found from interferometric studies that this criterion is satisfied for such relatively homogeneous materials as steel or cast bronze; the surface distortions shown by interferometry

nowhere extend more than 1¼ diagonals on either side. Our studies on single crystals of metals, however, have shown an unexpected contrary effect.

Fig. 13 is an interferogram taken on the surface of a single crystal of tin which has received an indent from a 100 gm. load—a light load since tin is a very soft metal. The first notable feature is the high degree of asymmetry. A striking aspect of this asymmetry was the discovery that the extensive "wings" reveal an elevation of the surface whilst the two smaller wings reveal a depression of the surface. The material had piled-up along one axis and had sunk-in along the perpendicular axis. The pile-up occurred in a strict crystallographic direction—parallel to the c-axis of the crystal—and extended much farther than the 1¼ diagonals tolerance (half the spacing) required by the Standards specification.

This interferogram shows the indents made on a single crystal must be placed very much farther apart. It also shows that if micro-hardness studies are to be made on small crystallites, these crystallites must be a good deal larger than was previously thought necessary, for the indent must obviously be a good distance from the crystallite boundaries if anomalies due to boundary effects are to be avoided. This should be taken into consideration by those who are making micro-hardness studies on the individual crystallites comprising alloys. The extent of the distortion in a single crystal was not even suspected before being revealed by the interferogram.

THE WEAR OF GLASS-CUTTING DIAMONDS

An interesting research project we carried out with multiple-beam interferometry was a study of the edge of the glazier's glass-cutting diamond to determine its life. Two types of diamond cutters are in use—one with a mechanically polished edge, the other with the sharp, curved, natural edge that is often found at the intersections of curved dodecahedral faces. We have studied a large number of both but only one example will be used to illustrate the application of interferometry to this problem.

A long glass cylinder 10 cm. in diameter was mounted in an automatic lathe with the cutting diamond set up on the tool

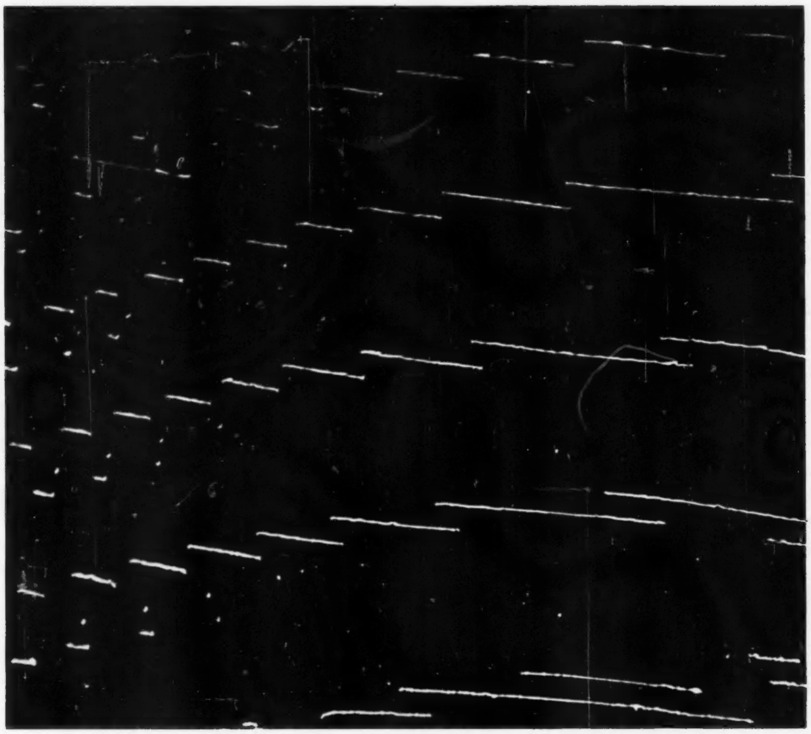
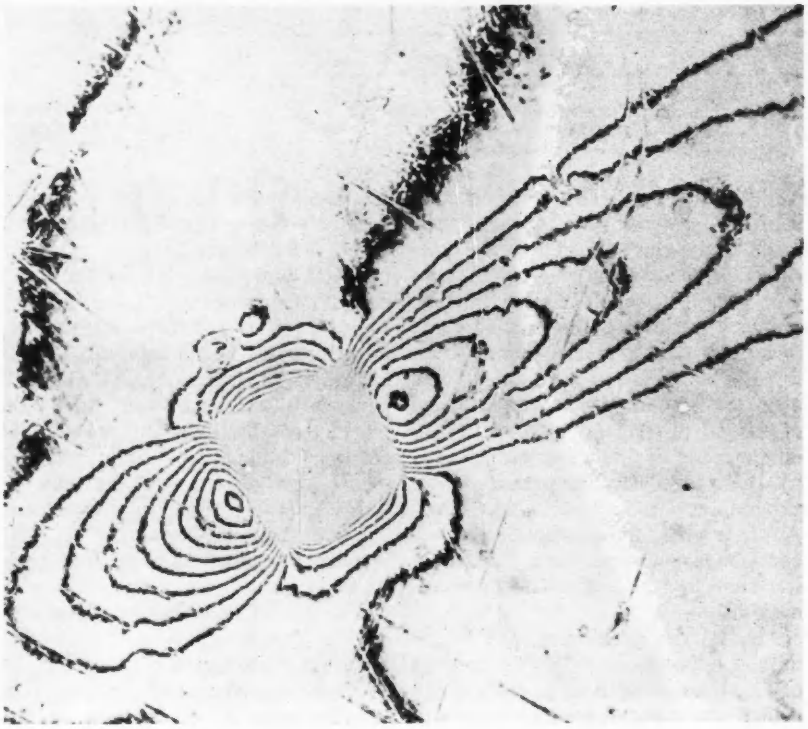


FIG. 12 (*above*). Another interferogram of a silicon carbide spiral showing fine definition possible with multiple-beam technique. Horizontal mag. 200×.

FIG. 13 (*below*). Indent on single crystal of tin. Horizontal mag. 80×.



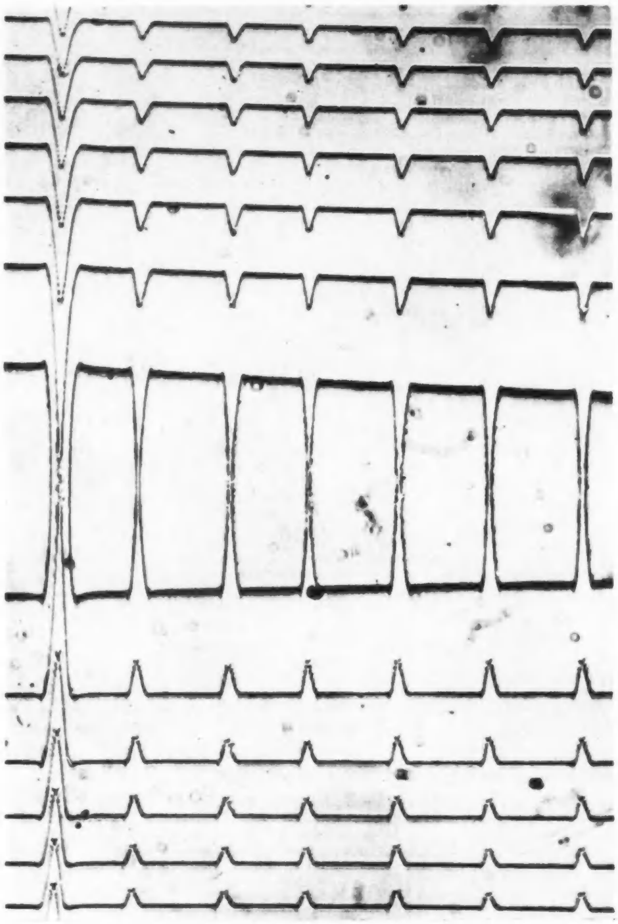


FIG. 14. Spiral cut made on a glass cylinder with a mechanically polished glazier's diamond, as seen on an interferogram. Horizontal mag. 150×.

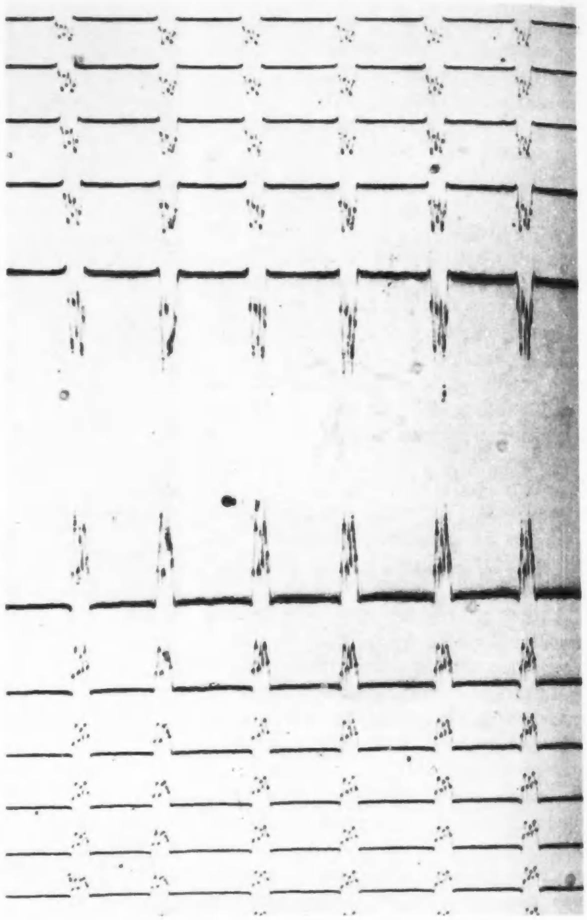


FIG. 15. Spiral cut on glass cylinder after cutting-edge of glazier's diamond has worn. Horizontal mag. 150×.

carrier. Using the screw-cutting arrangement, a long continuous helical cut was made in the glass cylinder. It was possible by this means to get a cut $1\frac{1}{2}$ miles long on a 2-ft. length of tube. In some of our experiments, this was repeated on ten cylinders so that cuts up to fifteen miles in length have been obtained with a single diamond edge. A cutting speed of about 1 m./sec. and an applied load of the order of 500 gms. was adopted for these tests after consultations with experienced industrial glass-cutters. After covering glass cylinders with a continuous cut, they were broken up into short lengths and studied interferometrically.

The interferogram produced by an untouched cylinder ordinarily consists of a set of straight lines parallel to the cylinder axis but spaced according to the familiar $\sqrt{n}$ law of the spacing of Newton's rings. The diamond cut put a kink in the fringe, the depth and shape of which was a measure of the sharpness of the cutting-edge of the diamond. Fig. 14 shows a multiple-beam interferogram at the beginning of the $1\frac{1}{2}$-mile cut, giving the true depth. Although great care was taken with the initial placing of the diamond against the rotating cylinder, the very first cut —that at the left—has an anomalous deepening due to the kinetic impact, slight as it was. The cuts thereafter became uniform until wear set in.

The shapes and depths of the cuts can be determined with considerable precision. At the start, they were about 1000 Å deep and small micro-cracks can be seen at the bottom of the grooves. The angle of the sides is deceptive as is always the case in an interferogram, since the magnification in depth is much greater than in the horizontal direction. The sides actually make an angle with the horizontal of only thirty-six minutes of arc—a very shallow cut indeed. The onset of breakdown of the cutting edge is easily established. A mechanically polished diamond lost its initial sharpness after only 100 metres when a 500 gm. load was used. The cut then became U-shaped, degenerated into a W-shape, and finally developed a complex profile, Fig. 15. Our tests confirm the traditionally held view that a natural dodecahedral edge is more long-lived than an artificially polished edge, although the artificial edge always starts off sharper than the natural edge.

EFFECTS OF HIGH-SPEED IMPACT

As a final example of what can be done with multiple-beam interferometry, an account will be given of some observations made on the distortion produced by the impact of a piece of rapidly moving metal with a stationary drop of water. This investigation was prompted by the problem of rain erosion of the surfaces of very high speed aircraft.

It has long been known that aircraft travelling at supersonic speeds through rain can suffer considerable surface damage, even on metal components of considerable strength. The effect was simulated in the laboratory as follows:

A drop of water, 2 mm. in diameter, was suspended on the end of a very fine fibre. A cylinder of the metal to be studied was then fired at the drop from a specially designed air gun. The end face of the cylindrical bullet was polished and the velocity just before impact was measured with two photo-cells placed 12 in. apart along the line of flight. The maximum speed attained was 850 m.p.h.

The damage produced by impact at speeds of this order is surprisingly large. Fig. 16 is an interferogram of the area of impact between an aluminium projectile and a drop of water. The fringes show a depression of 0·0001 in. over an area 1 mm. in diameter, and that the drop behaved somewhat like a solid sphere. The radius of curvature of the indent was found to be 55 mm. Since the radius of the suspended drop was only 1 mm., it is evident that the water drop has flattened considerably at impact, for any postulated elastic recovery in the metal could hardly account for so large a discrepancy.

An interesting discovery from these tests was that the volume of the indent increased at an enormously rapid rate with an increase in velocity. Within the relatively narrow range of our observations, we found that the volume of surface damage was roughly proportional to v^8—the *eighth* power of the velocity of impact. This is a fantastically high power relationship and indicates a very rapid increase in damage in the supersonic region. The limitations such findings place on high-speed flight will not be serious, however, since supersonic aircraft usually fly well above the level of rain clouds when they are travelling at their top speeds.

The second and final part of this article will deal with vibrating surfaces, the difficulties of using the multiple-beam technique for biological studies, and the use of fringes of equal chromatic order—an alternative interference system.

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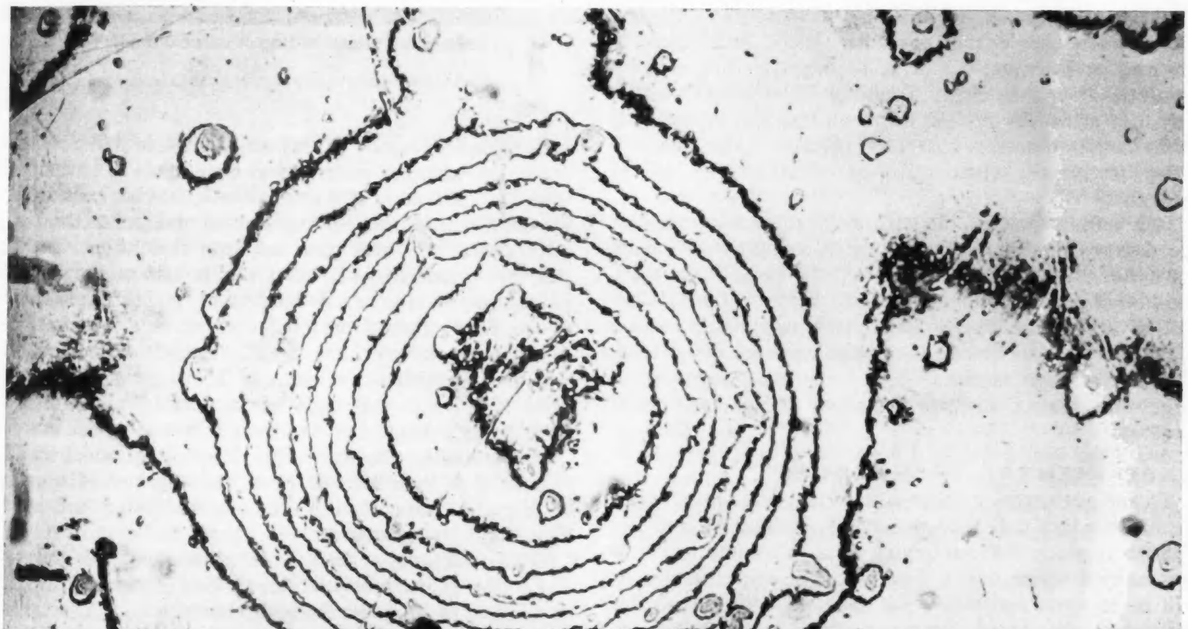
FIG. 16. Depression on aluminium surface produced by impact with a drop of water at 700 m.p.h. Horizontal mag. 130×.



DISCOVERIES ABOUT VIRUSES

MICHAEL STOKER

Recent research has led to the recognition of many new viruses and to fundamental discoveries about their nature that may one day help in the prevention and treatment of virus diseases.

A. Solitary cell placed in drop of nutrient fluid.

Considerable attention is now being given to viruses—not only in medical, veterinary, and agricultural laboratories, but also in centres concerned with general aspects of biology. There are several reasons for this. In the first place, viruses have at least some of the attributes which are associated with higher forms of life. They multiply, progeny resemble parents, and so on. Despite their complexity, they are definitely simpler than any other independent organism however, and because of this, some understanding is being obtained about their chemical and physical nature and the way they grow. As models of certain essential growth and reproduction processes that take place in more complex living organisms, viruses are of great interest to all biologists.

They are also drawing the attention of researchers because the diseases they produce in humans, animals, and plants are not only common but remain a challenge at a time when most other infectious diseases have been brought under control of antibiotics. Paradoxically, the new tissue culture techniques used in virology—of great value for the production of protective vaccines—have led to the recognition of large numbers of hitherto unknown viruses and virus diseases.

EXPERIMENTAL TECHNIQUES

To find out anything about viruses, it is necessary to grow them. Since they only grow inside living cells, it is obviously difficult to study the multiplying virus in an intact laboratory animal where only a few probably unidentified cells will be infected and where the enormous complexities of the system will obscure the observations. It is preferable to work with the simplest essential system—the virus and a uniformly susceptible population of cells in a test tube where many of the variables can be rigidly controlled. For this reason, the most rewarding studies so far have been with bacteriophages—viruses which grow in living bacteria. However, technical progress has been made in recent years with the cultivation of mammalian and avian cells *in vitro* so that it is now possible to grow and manipulate these cells with almost the same ease as bacterial cultures. Cell suspensions can be grown directly from human or animal tissue or can be obtained as sub-cultures of "stable" lines of cells which, like standard bacterial cultures, are propagated in laboratories all over the world. Homogenous cultures can be prepared by isolating colonies or clones grown from single cells. Fig. 1 shows a single human cancer cell cultured in isolation in a drop of growth fluid, followed by cell division and, eventually, the formation of a colony which can be subcultured. Pure lines of virus can be grown in a similar fashion by sub-culturing from foci initiated cell sheets by a single virus particle.

When uniformly susceptible populations of cells are exposed simultaneously to suspensions of virus particles, it is possible to study the change in the cells and the synthesis of new virus in the bulk cultures, and thereby reach conclusions about the changes in each individual cell. In some cases, it is also possible to collect the newly formed virus, free it from extraneous host material, and then examine it chemically as well as with the electron microscope. These and other types of experiments have led to new discoveries about the nature of these organisms and their growth.

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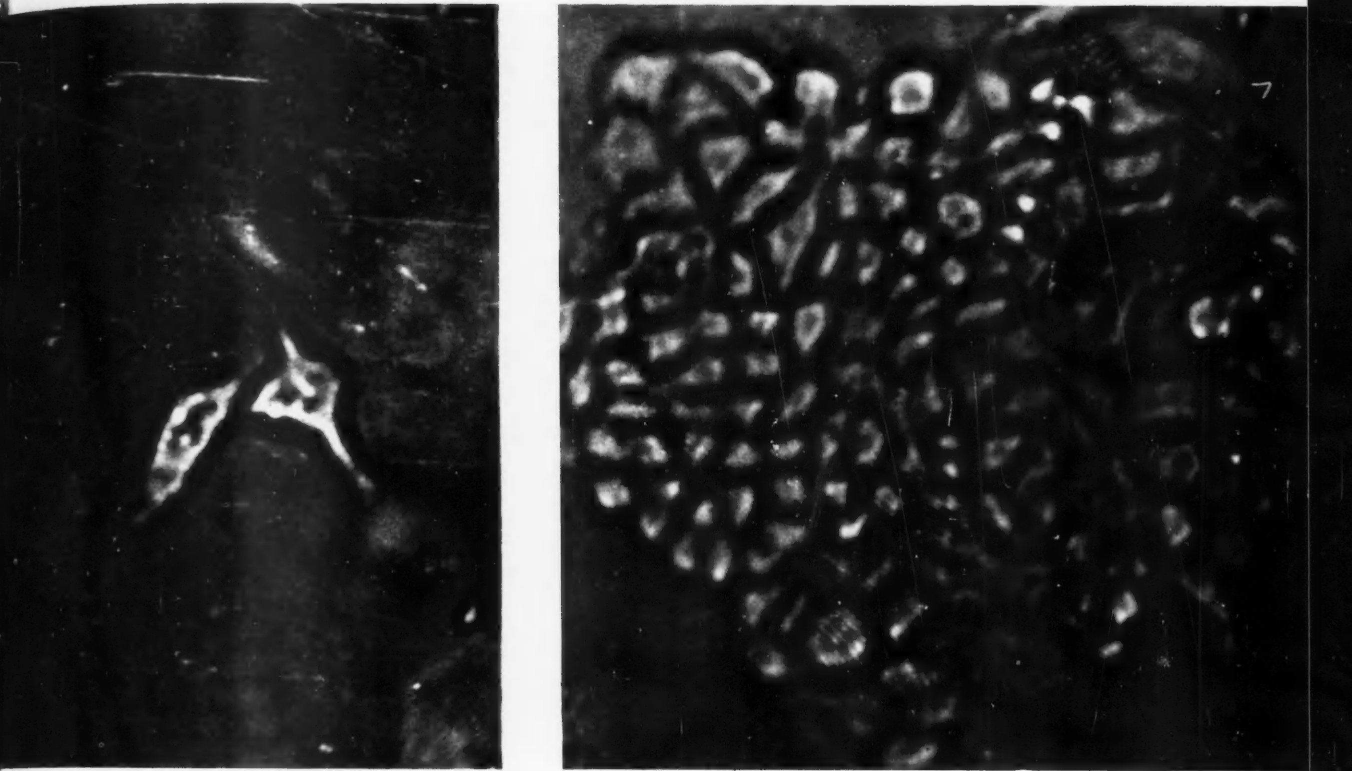


B. First division. C. Colony derived from single cell.

FIG. 1. Growth of clone of human cancer cells from a single cell. 1200×.

THE COMPOSITION AND STRUCTURE OF VIRUSES

The bacterial and plant viruses that have been examined are composed of protein and nucleic acid (deoxyribonucleic acid, DNA, in bacteriophages and ribonucleic acid, RNA, in plant viruses). It has been found that small animal viruses (for example, the poliomyelitis virus), similar in size to many plant viruses, also contain RNA and protein alone. Other small viruses and most of the larger ones (for example, the influenza virus) contain fat and carbohydrate as well, but it is possible that these come direct from the host cell and are not made as part of the virus synthesis. A few viruses of higher animals, on the other hand, have been found to contain DNA. Insect viruses (which must be included with the animal viruses) also contain DNA.

In 1956, two Cambridge workers, Drs F. Crick and J. D. Watson, suggested on purely theoretical grounds that virus protein should be built up as a number of identical sub-units, and that a certain limited number of geometrical arrangements would give a spherical shape. Striking confirmation of this hypothesis was produced when details of the structure of single virus particles were revealed by the development of a new electron microscope technique. Developed by Dr S. Brenner and Mr R. Horne, also of Cambridge, this technique gives resolutions down to 15Å.

All of the small and medium-sized viruses examined so far have been found to be composed of sub-units arranged in a regular geometric pattern to form a solid polyhedral figure, with the nucleic acid presumably in the centre. The sub-units are probably protein and may consist of one or more protein molecules.

A single adenovirus particle examined by this technique and shown in Fig. 2 was found to contain 252 sub-units arranged in triangular faces. A group of poliovirus particles, seen in Fig. 3, turned out to be morphologically similar to a virus affecting turnips. A few, such as the herpes virus of Fig. 4, were found to contain hollow sub-units. These virus particles just described are the mature forms released by infected cells, and can enter and infect new cells. During the multiplying or "vegetative" phase inside the cell, infective virus particles lose their identity; they do not simply divide by fission, like bacteria.

THE INFECTION PROCESS AND ITS GENETIC SIGNIFICANCE

In 1952, new light was thrown on the process of virus multiplication by two Americans, Drs A. D. Hershey and M. Chase. They found that the tadpole-like bacteriophage particle does not enter the bacterial host cell during infection but that it is, rather, the nucleic acid from the head of the particle which enters and initiates the production of new particles. In 1956, Dr H. Fraenkel Conrat in the U.S.A.

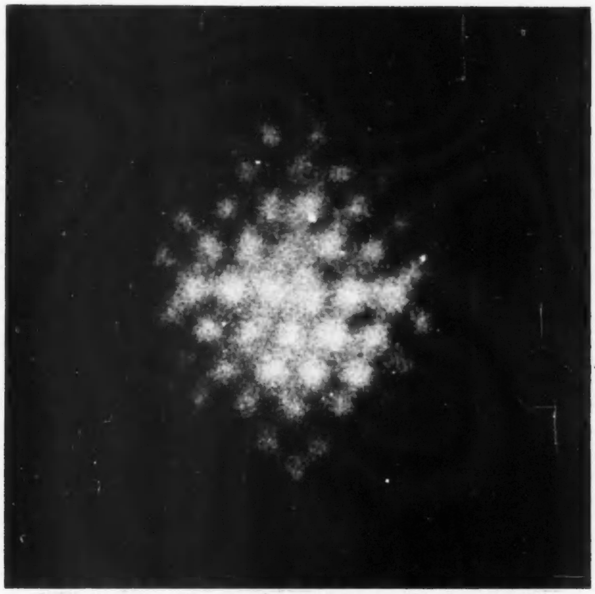


FIG. 2A. Adenovirus particle at high magnification, 700,000×.

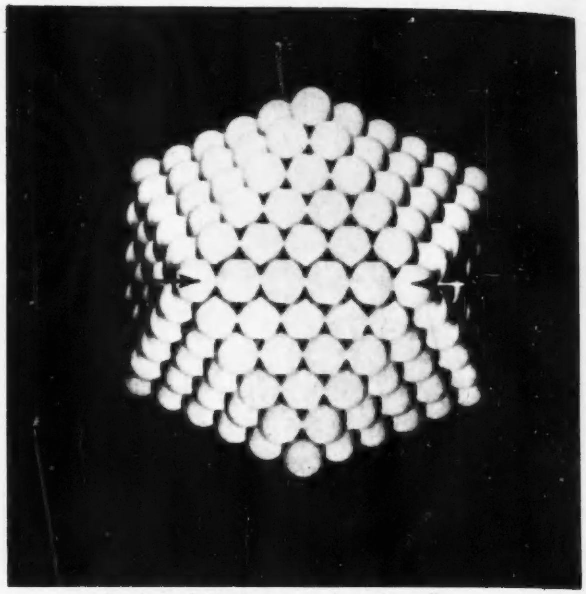


FIG. 2B. A model in the same orientation.
Horne, Brenner, Waterson, Wildy, J. Mol. Biol., *1959, Vol. 1.*

and Drs A. Gierer and G. Schramm in Germany separated the RNA from the protein of tobacco mosaic virus and found that the intact particle was not essential for infection. The extracted RNA itself initiated infection in the cells of a tobacco plant and led to the production of complete particles containing both protein and nucleic acid.

In the last two years, infective RNA has been extracted from cells infected with poliomyelitis virus and several other viruses affecting man and animals. As a result, we now believe that—with all the smaller viruses at least—infection starts in a cell when the nucleic acid thread of the virus is released from its protein coat. Except for bacterial viruses, this probably takes place inside the cell although the naked nucleic acid extracted from viruses can also penetrate the cell from outside in a rather inefficient manner. After the appearance of new enzymes in the cell, the nucleic acid thread begins to replicate and this is accompanied by the synthesis of virus protein. Under certain conditions, the protein units accumulate around condensations of nucleic acid, and form complete virus particles, some of which are released and infect new cells.

The discovery of the infectivity of nucleic acid, besides throwing light on virus multiplication, has a much wider significance. It is one of the most important advances in biology because it shows conclusively that genetic characters can be carried in nucleic acid alone, either in DNA or RNA.

The new knowledge gained about virus multiplication has not yet shown a way of preventing virus growth without damage to the host. In fact, it stresses the difficulty of the problem since synthesis of viral and cellular components are probably along similar metabolic paths. However, a substance called "interferon", discovered by Drs A. Isaacs and J. Lindemann in London, has aroused much interest. (See DISCOVERY, 1958, vol. 19, No. 7, p. 266.) They found that when influenza viruses were damaged by mild treatment with ultraviolet light or heating, they would not multiply. Instead, these particles made the cells produce a peculiar protein, interferon, which not only prevented the growth of the undamaged influenza virus but prevented the growth of many other viruses as well. Interferon does not act until after the virus enters the cell; the mechanism of inhibition is still unknown and it is impossible to say at this point whether the substance will have any practical use in medicine. It nevertheless merits and is receiving intensive study.

VIRUSES, OLD AND NEW

Now that human cells and similar monkey cells are available in test-tube cultures, it has been possible to isolate and study viruses from man which will not grow in ordinary laboratory animals. Heretofore, some of them could be studied only in scarce animals such as monkeys or chimpanzees, or with the help of human volunteers. The use of tissue cultures has not only made possible the large-scale production necessary for a poliomyelitis vaccine but has also allowed the extensive laboratory tests necessary to prove its safety and efficacy. Measles virus can also be grown and studied in test-tube cultures and it is likely that a vaccine for this disease may soon be available. Even that notorious and ubiquitous creature—the common cold virus—has at last been cultivated in human cells after many years of painstaking work by Drs Andrewes, Tyrell, Pereira, and others at Salisbury. This very recent and important step should now yield a great deal of information about colds and the way they spread, and may soon indicate whether a vaccine is practicable.

The virus of trachoma, a cause of widespread blindness in the Middle and Far East, is second only to the common cold in the number of people it affects. This virus is an

obligate intracellular parasite but it belongs to a group of large viruses which somewhat resemble bacteria. Although it is susceptible to penicillin which is now being used very extensively for treatment, the inability to cultivate and study this virus in the laboratory until recently has handicapped investigations of the mode of spread and the reservoirs of infection which should be eliminated. Dr Chang and his colleagues in China, and Dr Collier and Dr Sowa in Britain have now isolated and propagated the virus in the cells of fertile chick embryos, opening up great possibilities for the further study and eventual eradication of this disease.

Apart from the isolation of the causative virus of these well-known diseases, the use of human and monkey cells has led to the isolation of a series of new and previously unsuspected viruses. Many of these have been found in healthy as well as sick persons, and it has not been easy to identify a disease to fit a given virus. This is why they were first known as "orphan viruses".

These new viruses fall into two groups: (1) those found mainly in the intestinal tract, now known as enteroviruses and (2) those of the respiratory tract, comprising a family known as the adenoviruses (see Fig. 2) and some new viruses of the influenza group. Many of the enteroviruses were found during the attempted isolation of the poliomyelitis virus from faeces; they may, in fact, cause illnesses in childhood like mild poliomyelitis without paralysis. The poliomyelitis viruses are included in this group.

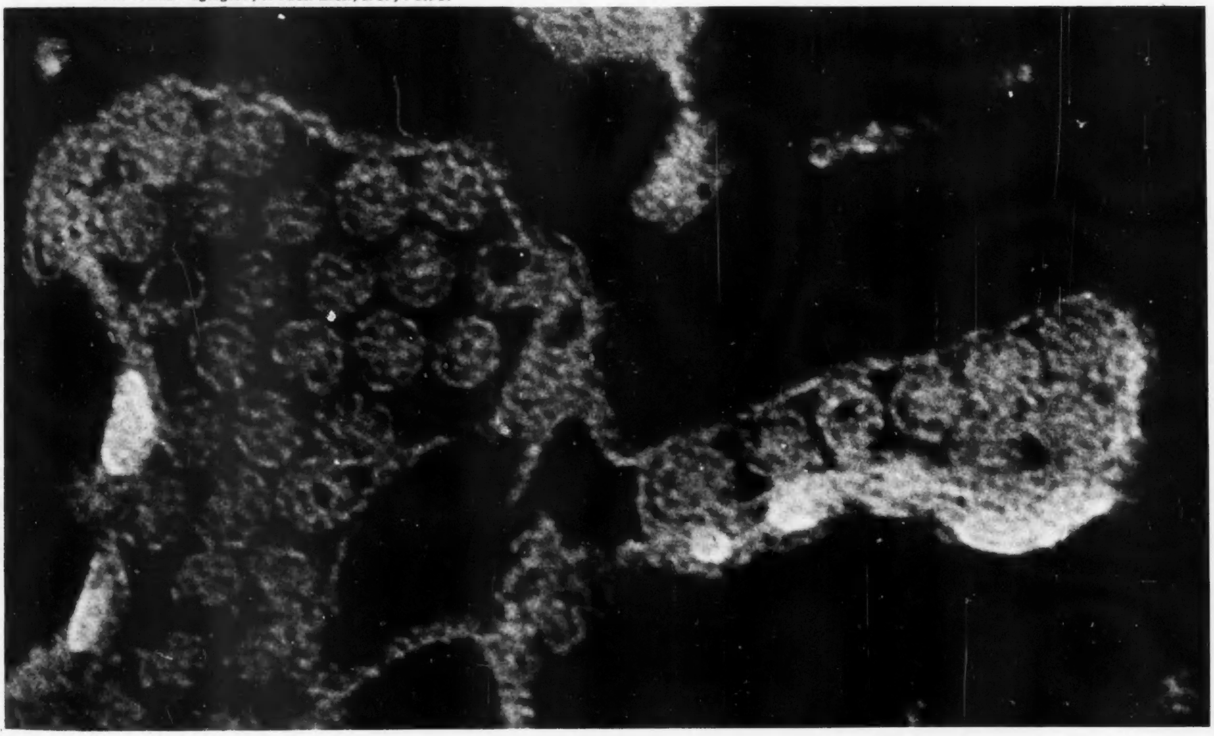
The adenoviruses were discovered in a different way. In the early days, there was a shortage of human tissue and attempts were made to use cultures of tonsils and adenoids removed by operation. The majority of these cultures eventually degenerated and this degeneration was found to be caused by latent viruses present in the original tissue. Similar viruses were found in patients with pneumonia and other diseases of the upper respiratory tract and also in certain acute infections of the eye. The adenoviruses causing all these diseases are all related. Some types apparently enter in infancy and may remain in tissues such as tonsils and adenoids for many years. Others come and go like other acute infections.

INFLUENZA AND MYXOMATOSIS

One virus has made its own dramatic contribution in recent years without the aid of virologists. The influenza virus, known to cause large epidemics, produces variants that are slightly different from their predecessors and therefore able to grow better in humans immune to the earlier strains. A variant which appeared in China in early 1957 was so novel the whole population of the world was completely susceptible. Within a year, half the population was infected, according to estimates made.

A similar but more lethal process was started deliberately with the intention of eliminating rabbits first in Australia and later in France. When myxomatosis was successfully introduced in Australia in 1950, and later into France, nearly all of the Australian rabbits and a high proportion of the European rabbits subsequently

FIG. 3. Group of particles of poliomyelitis virus, 430,000×.
Horne and Nagington, J. Mol. Biol., 1959, Vol. 1.



succumbed. An increasing number are now surviving infection, partly through selection of the genetically more resistant animals, and it is expected that myxomatosis will eventually be a mild disease in the new resistant strains of rabbits. It may be that the relatively harmless and common viruses of man, such as many of the enteroviruses and adenoviruses, began by causing holocausts resembling that produced by myxomatosis.

CANCER

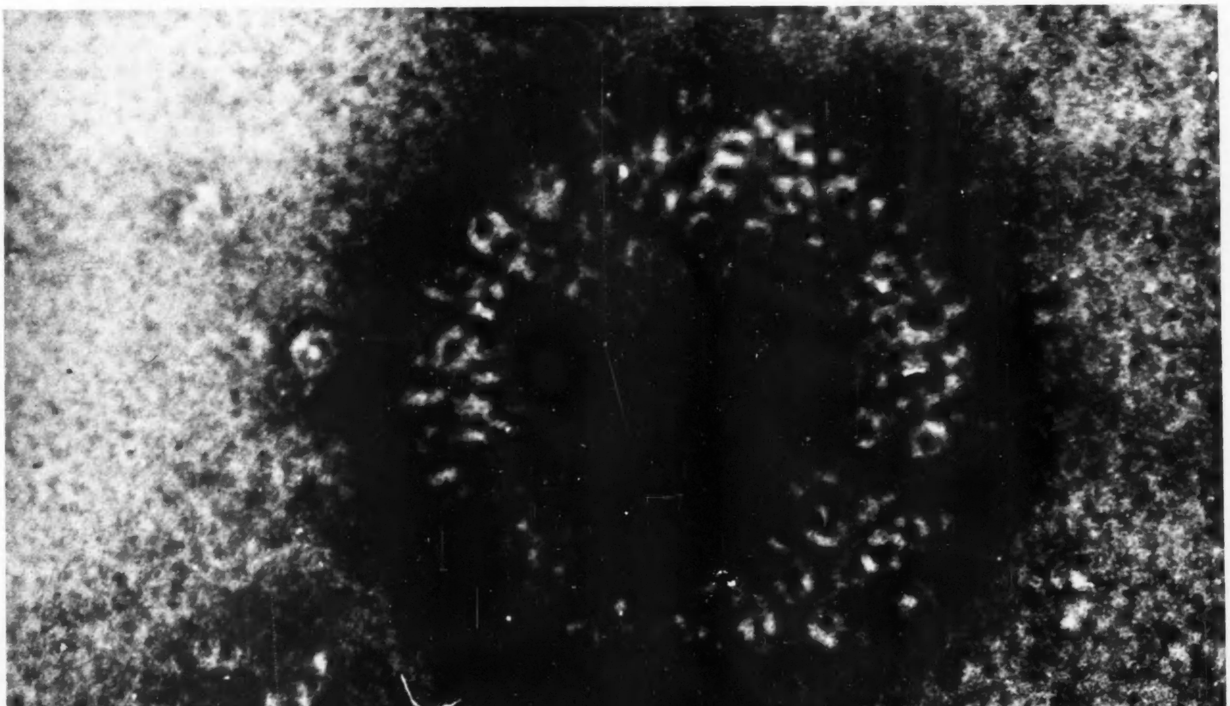
The recent years have seen a mounting interest in the viruses which cause cancer. It is nearly fifty years since Dr Peyton Rous first isolated a virus which caused cancer in chickens and although work on this and a few similar viruses has continued, research has been somewhat hampered by the difficulty of observing the initial changes (involving only a few cells, perhaps) in the enormous complexity of an intact bird or animal. Dr Rubin and others have now shown how the virus-induced change from a normal to a cancer cell can be observed directly in tissue culture under closely controlled conditions. This may well lead to a better understanding of how cancer is started, not only by viruses but by other factors as well.

Some important new groups of cancer viruses have been discovered recently. One type—the polyoma virus—is apparently quite common as a natural infection in both laboratory and wild mice. Attempts are now being made to isolate viruses from human cancer but it is impossible to prove directly that the viruses obtained are capable of producing cancer in human beings. The potentialities of any viruses isolated from human cancer will have to be assessed indirectly, presumably in human cells in culture.

The coming years are likely to bring an increasing knowledge of the molecular structure and growth of viruses which may help towards a better understanding of the synthetic process in the living cells which act as hosts. We may find that some diseases which are not suspected as infections in the ordinary sense may be due to viruses or even to abnormal nucleic acids which are not built into conventional virus particles.

Advances in knowledge may not lead quickly to the discovery of any practical therapy for virus diseases but it is probable that vaccines will come along that are effective against many more virus diseases and that they will take the form of living but harmless variants of the causative virus.

FIG. 4. Herpes virus particle at high magnification showing hollow sub-units. 1,000,000×.
Horne, Brenner, Waterson, Wildy, J. Mol. Biol., 1959, Vol. 1.



THE LAST ALCHEMIST

J. H. S. GREEN

Under pressure from the Royal Society to prove his claims, James Price, M.D., F.R.S., committed suicide in front of an investigating committee. The fact that alchemy was still taken seriously a century after Boyle defined the concept of "element" shows how small an impact science made outside a narrow circle during the 18th century.

James Price, M.D., F.R.S. (1752–1783).

In the summer of 1782 there appeared a pamphlet entitled "An Account of some Experiments on Mercury, Silver and Gold, Made at Guildford in May, 1782. In the Laboratory of James Price, M.D., F.R.S. . . ." Under this simple and prosaic title was yet another claim to have realised the old chimera of alchemy, for this pamphlet claimed the transmutation of mercury into silver and gold. A little over a year later, on August 3, 1783, its thirty-one-year-old author was to commit suicide in front of three members of the Royal Society sent to observe and report on his process. Such is the story of one of the last episodes in the long history of alchemy, a story therefore not without interest quite apart from its dramatic ending.

Price was born in London in 1752 as James Higginbottom, and was educated at Magdalen Hall, Oxford, where he graduated M.A. in 1777. Four years later his uncle, James Price, bequeathed him capital of some £10,000 together with an annual income of £130 on condition that the young man assumed the name of Price. This he did and at the same time, early in 1781, he was proposed for election to the Royal Society. That he was actually elected, on May 10th of that year, is perhaps the first curious thing about Price's career. He was described as a "Gentleman well versed in various branches of Natural Philosophy and particularly in Chymistry", although at this time he had published nothing on chemistry, and in fact no record exists of any other chemical work by him whatsoever, other than his writings about the alleged transmutations. His eleven supporters in the Royal Society included the Astronomer Royal, Dan Solander, and Richard Kirwan. Solander was a close friend of Sir Joseph Banks (who at thirty-eight was then in his fourth year as President and where he was to remain for the next thirty-eight) and had sailed with him and Captain Cook in the *Endeavour*. So his support for Price, though unexplained, must have been

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of great value. Kirwan, on the other hand, was an eminent Irish chemist and mineralogist, and a well-known scientific personality of his time. All of the supporters, and Banks himself, were to be more than a little embarrassed by the subsequent activities of their protégé.

Meanwhile, with his fortune, Price had bought a country estate at Stoke, near Guildford, set up a well-equipped laboratory and begun experiments. From the beginning his avowed aim seems to have been alchemical, with the particular objective of transforming mercury into gold or silver. He subsequently wrote: "A frequent perusal of ancient chemical writers, and an early attachment to the metallurgic branches of Chemistry inclined (Price) to believe that the wonders related in books at present little read, though frequently exaggerated, had at least some foundation. The phenomena which he continually met with in the pursuit of his experimental inquiries contributed greatly to strengthen this opinion." Price held that a belief in the transmutation of metals "seemed to be very easily reconciled with the notions of more modern chemists", and adduced as evidence the old argument concerning the "remarkable analogies between the habitudes of silver and mercury, to chemical solvents and other agents, . . . known to every Chemist".

He therefore set out to follow the traditional path and worked throughout 1781 seeking a substance which, in small quantity, would bring about the required changes. By May of 1782 he decided that he had found two such materials in the form of powders. A white powder was alleged to change fifty times its own weight of mercury into silver, whilst a red powder was alleged to change sixty times its own weight of mercury into gold. The composition of these powders, as might be expected, was not stated. They apparently contained arsenic and, Price was later to claim, their preparation involved "a process tedious and operose", and was unhealthy. The powder, white or red, was added to the mercury together with a flux and the whole mixture fused in a furnace. On cooling the result was a mass of

An engraving of the period titled "The Alchemist in His Laboratory" by Michel Plonski (1778–1812), after a painting by D. Teniers (1610–1690).
From the British Museum, London.

silver or gold of weight equal to that of the original mercury. In his method, therefore, Price was again the traditional alchemist. Curiously, all the original samples of the powders were used up in the demonstrations.

These demonstrations were given at Guildford in his own laboratory, initially before some of his neighbours but later, as the rumours spread, a wider group of witnesses appeared. In all nearly twenty people attended the seven demonstrations given by Price between May 6 and 25, 1782. Although they included some distinguished people, including Lord Palmerston, the father of the statesman, as well as two other fellows of the Royal Society, no chemists were present.

Within a few weeks Price's fame spread widely, considerably helped by his own published account; this was the pamphlet, published at Oxford by the Clarendon Press. But even before it appeared Oxford had seen fit to honour Price in its own way—by giving him the M.D. degree, an event in some ways even more extraordinary than his election to the Royal Society. For he was allegedly given it "in recognition of his discoveries in natural science, with special references to chemistry". Since he had published no other chemical work apart from the alchemical experiments the conclusion seems inescapable that it was these alone which had earned him the degree.

But if Oxford was prepared to honour Price in this uncritical way, reaction in other quarters was rather different. Sir Joseph Banks wrote on July 14 of being "entertained by Mr Price, formerly Higginbottom, fixing mercury into gold and silver at his pleasure". Similarly Kirwan "at first thought he was in jest . . . and fancied that Price meant nothing more than to make the country people stare". But this light-hearted view soon turned to irritation and anger and Banks wrote, "Kirwan and indeed all the chymists are angry at such an apparent charlatanism". The uncritical appraisal of Price continued, however. Dr Charles Blagden, a close friend of Banks and shortly to be Secretary of the Royal Society, wrote in a letter to the President in August that "the monthly reviewers have inserted just such a criticism of Price's publication as one might suppose he himself would have drawn up if he had been employed for the purpose". Two months later the publicity was helped along yet further by a lengthy summary of the book which was published in the London Chronicle for October 17th–19th. By now Banks was writing of "our Paracelsus of Guildford" and reported that Kirwan was "violent, almost determined to propose his expulsion from the Royal Society".

In spite of his obvious anger Banks was unwilling to take such a course, and in this he was wise for to do so would undoubtedly have raised a storm of protest from the public. Even Blagden seemed more worried about the impropriety of Price's behaviour than the fraud itself. Price had become a public figure and the public would not have lightly tolerated his being dismissed as a charlatan. Had not samples of the "artificial" gold received the honour of inspection by the King? No, Banks could not act precipitously, but instead wrote directly to Price and warned him that the reputation and honour of the Royal Society were placed in jeopardy, and insisted on a repetition of the experiments. To this Price replied very much on the defensive: the demonstrations had been given before adequate witnesses and that their repetition would serve no useful purpose. This view he supported on the grounds that ". . . as the spectators of a fact must always be less numerous than those who have heard it related, so the majority must at last believe, if they believe at all, on the credit of attestation". He was now prepared to admit the further fact that the cost of the whole process was greater than the value of the gold produced, some £17 being spent to obtain £4 of gold.

William Godschall, one of the observers at the seventh of the original series of demonstrations, was now employed to act as a messenger between Banks and Price. He eventually reported back as follows: "I saw Dr Price and told him one of two things was expected of him, either to repeat the experiments at a foreign laboratory or disclose the composition of the powder. He said he would wait on you previous to the next meeting and learn, *ex cathedra* all that was required of him." Further to this Price returned to Guildford in January 1783 ostensibly to make preparations for the fresh set of demonstrations. Then for the next six months nothing more was heard of him!

He had in fact gone to Germany where the publication in Dessau of a translation of his book caused yet another considerable stir. For a while it might have been that his reputation was to grow still greater, but in fact Price had shot his bolt. In August of 1783 he returned again to Guildford and shortly afterwards three delegates from the Royal Society travelled down there. Price met them calmly and in the laboratory proceeded to prepare for a demonstration. After a short while he left the room, swiftly drank some poison previously prepared—and returned to collapse and die in front of his visitors.

What are we to conclude about Price? Was he insane, or a fraud, or even the victim of a fraud? We shall never know, though the verdict of the inquest was that he was of unsound mind. But perhaps the most notable feature of the whole story is that Price was really a man too late for his time by some hundred and fifty years at least. The scientific world of the 1780's would not take him seriously for a moment, but the public reaction was sufficiently violent to cause even the Royal Society to be wary of dismissing him out of hand. It is remarkable that notice of Price's claims had to be taken in academic circles, albeit in a negative way. Even the great Prof. Joseph Black of Edinburgh did so, explaining that "my only intention in this was earnestly to dissuade my pupils from giving way in the least to the ruinous notions and pursuits which Dr P's publication, so far as it may be credited, would have a tendency to encourage".

That this was necessary at so late a date shows how small an impact 18th-century science had made outside a narrow circle. Beyond this circle alchemy was not entirely discredited even a hundred years after Boyle's *The Sceptical Chymist* had defined the concept of "element" in such a way as to make much of modern science possible. But Price was certainly the last of his kind, the last to make alchemical claims of which notice had to be officially taken by an eminent scientific society.

MODERN LOW-NOISE AMPLIFIERS

Part II: MASERS

I. M. STEPHENSON and G. D. SIMS

The final section of this two-part series deals with Masers which, along with the parametric amplifiers discussed in Part I, have opened up new possibilities for long-range communication and radio-astronomy. The latest development, the light amplifier or Laser, may be the answer to the increasingly critical problem of crowding in the communication spectrum.

Certain substances when irradiated by electromagnetic energy at microwave frequencies are capable of partially absorbing it. It is often characteristic that the absorption takes place at very sharply defined frequencies and the substance thus acts as a resonant circuit, storing electromagnetic energy. As it is also possible for the substance to re-emit radiation at the same frequency, the whole process is completely analogous to the emission and absorption of visible light in the optical spectrum. How molecular substances can be employed as resonant elements and, moreover, how they can be used to produce amplification at high frequencies is the subject of the second and final part of this article on low-noise amplifiers.

The molecular amplifiers alluded to are known as Masers, the term coming from the initial letters of the process by which they amplify: Microwave Amplification by Stimulated Electron Radiation. They are potentially useful as low-noise oscillators as well as low-noise amplifiers and, in view of the sharpness of the molecular reasonance in some cases, are particularly useful as primary frequency standards. We will be concerned here with the low-noise amplifier application, for the most part.

It is generally accepted that the first device of this type was made by Gordon, Zeiger, and Townes in the United States in 1954, although Prokovsky in the Soviet Union was having similar thoughts at about the same time.

THE AMMONIA MASER

Although the most promising Masers at the present time are solid state devices, the simplest one to understand is the Maser that uses ammonia gas—the first one to work successfully. This Maser uses the two basic energy states of the ammonia molecule, NH_3. In the lower-energy state, the nitrogen atom is practically stationary and is almost in the plane of the three equidistant hydrogen atoms. In the high-energy state—to which the molecule can be raised by the absorption of a quantum of energy at the proper frequency—the nitrogen atom oscillates perpendicular to the plane of the hydrogen atoms, between positions a and b of Fig. 2. The energy stored in the molecule thus depends on its state. Since the lower-energy state is the one of stable equilibrium, more molecules will be found in this condition under normal circumstances than in the higher-energy condition.

When the gas is irradiated at a frequency given by

$$f = \frac{\Delta E}{h}$$

where ΔE is the difference in the characteristic energies of the two states and h is Planck's constant, some of the radiation is absorbed, elevating a number of molecules to the higher-energy state. When, on the other hand,

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FIG. 1 (*left*). This tiny ruby crystal is the heart of a Maser amplifier. (*U.S. Army*)

a molecule falls from the upper to lower state, a quantum of energy is emitted at the resonant frequency. Under normal circumstances, the gas contains molecules in all possible energy states, the number of molecules in any one state decreasing exponentially as the energy associated with the state increases. Thus there will always be more molecules in the lower of the two states that we are considering.

If now, the molecules in the lower state could be removed by some means, we should be left with a gas containing an excess amount of energy stored at the resonant frequency. The molecules in this upper state, if left to themselves, would all fall back to their lower state in time with the consequent emission of radiation, but no useful purpose would be served since the times at which the molecules radiated would be completely random. If, however, these higher-energy molecules are irradiated by electromagnetic energy at the resonant frequency, then a process of "stimulated radiation" or "induced emission" takes place. When the irradiating field is at its peak, a large number of molecules radiate and fall back to the lower-energy state; when the field is zero, the number radiating is small. Thus, the radiation from the molecules reinforces the irradiating wave and hence amplifies it. Since the resonance frequency for ammonia is in the region of 24,000 Mc/s, this is the frequency at which the ammonia Maser usually works. If we want a Maser to operate at a different frequency, we must find a molecular gas with suitable resonance lines at that frequency (if we can). A schematic diagram of an ammonia Maser is shown in Fig. 3A. This arrangement works as a result of the convenient fact that ammonia molecules in the lower-energy state acquire a dipole moment under the action of an electric field due to the displacement of the positive charges within the molecule with respect to the electrons. The device functions as follows: a beam of ammonia molecules is formed and passes into a non-uniform electric field that is produced by a quadrupole focuser, shown in Fig. 3B. The lower-energy state molecules are dispersed towards the region of greatest field strength (outwards towards the quadrupole itself) while the molecules in the upper state remain in the region of lower field strength (near the axis). The "active" gas along the axis then passes into the cavity resonator, where the input signal to be amplified induces "stimulated radiation". This causes the

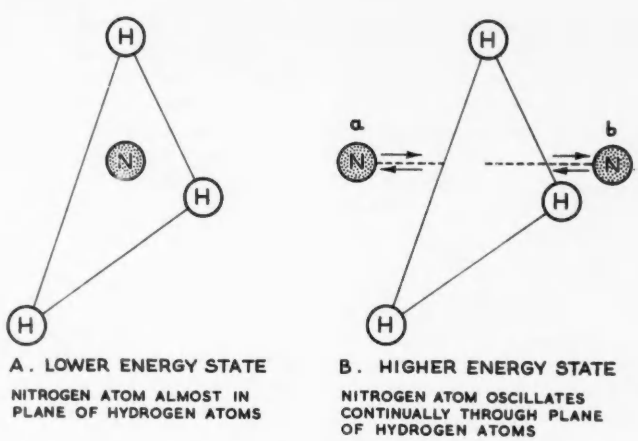


FIG. 2. The basic energy states of the ammonia molecule, NH_3.

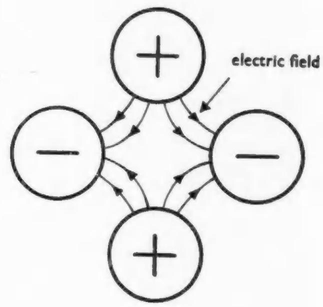
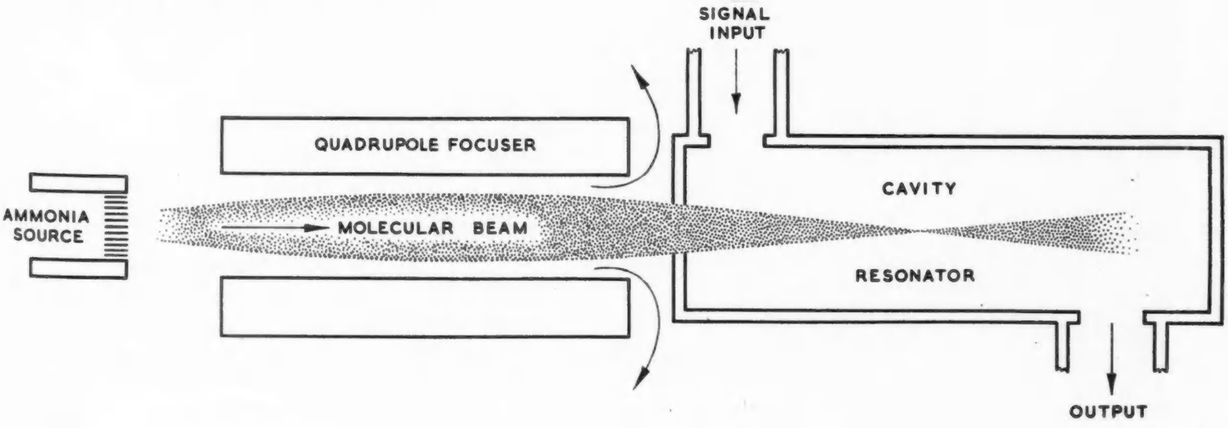


FIG. 3B. Cross-section of quadrupole focuser.

FIG. 3A. Schematic diagram of an ammonia Maser.



field in the cavity resonator to grow in amplitude and an amplified signal can be taken out at the output port.

Devices of this type have operated with gains of 10 db (power gains of 10) over a frequency band of a few kc/s with noise temperatures of about 80°K. (The noise temperature is an effective measure of the output noise power and is defined as that temperature at which an equivalent resistance would generate the same amount of noise in the bandwidth of the device.)

The ammonia Maser exhibits the two main properties common to all Maser-type devices. First, the electromagnetic wave to be amplified travels in an *active* medium in which the wave *grows* in amplitude. Secondly, coherent radiation is obtained from the active medium as a consequence of the fact that the probability of transition from a high-energy state to a low-energy state is a maximum when the irradiating field is a maximum.

The various types of Maser differ principally in the way in which the active medium is produced. Maser action can be obtained whenever one can produce a medium in which more atoms or molecules are in a higher-energy state than in a lower-energy state, for the medium can always be persuaded to yield this energy to an irradiating wave.

Many methods have been proposed for the production and use of active media but we shall only be concerned here with the device which has so far shown the greatest practical promise, namely the three-level Maser. We shall then be in a position to compare the properties of Masers with parametric amplifiers and indicate where their present advantages and disadvantages lie, as well as their future possibilities.

THE THREE-LEVEL MASER

The three-level Maser was first proposed by Bloembergen in 1956 and depends for its operation on the fact that some paramagnetic substances—some crystalline forms in particular—exhibit electron spins at a number of discrete energy levels, even without an applied magnetic field. The three-level Maser also makes use of the fact that any applied field will alter the relative spacings between any three such chosen levels.

As already stated, the number of electrons, atoms, or molecules in a particular energy state falls off exponentially as the energy of the state increases. For any three levels, the number of electrons in each state—the "state population"—might be as indicated in Fig. 4A. If the state energies are E_1, E_2, and E_3 as shown, the substance will be capable of absorbing radiation at any of the following frequencies:

$$f_{13} = \frac{E_3 - E_1}{h},$$

$$f_{23} = \frac{E_3 - E_2}{h},$$

$$f_{12} = \frac{E_2 - E_1}{h}.$$

When the substance is irradiated at a frequency f_{13}, energy will be absorbed and electrons will be elevated from state 1 to state 3. At the same time, induced emission will occur with electrons in state 3 radiating and falling back to state 1. If the interchange of electrons between the two levels takes place rapidly enough, a condition of dynamic equilibrium can be reached at which the populations of states 1 and 3 become equal (Fig. 4B). There will then be more electrons in state 3 than state 2 and a possible method of using the medium becomes apparent. Irradiation of the system at a frequency f_{23} will now result in "stimulated radiation" as the excess population of state 3 fell back to state 2.

There will, of course, be an elevation of some electrons from state 2 to 3 by the incident radiation, but the number that fall from state 3 to 2 will be larger, since there are more electrons in state 3

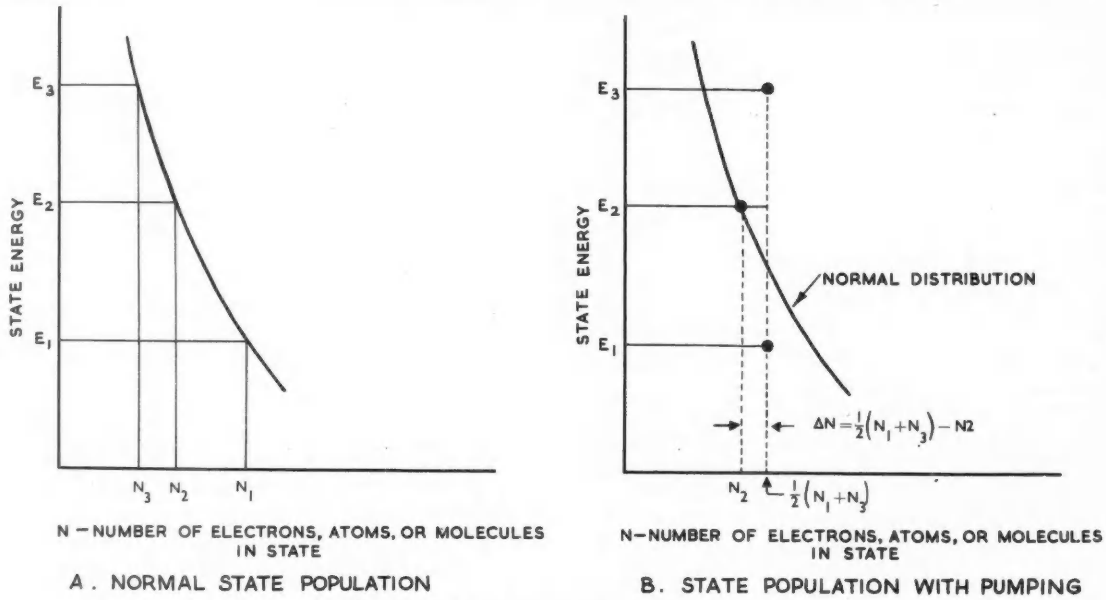


FIG. 4. Characteristics of three-level crystal.

that in state 2; the net result will be an enhancement of radiation, rather than absorption. The population of state 3 can be maintained by putting in energy at the frequency f_{13} to "pump" electrons up from state 1.

A similarity to the parametric amplifier can be noted, for here is another device in which energy at one frequency (f_{13}) is converted into energy at another frequency (f_{23}). Both share the disadvantage of requiring pump sources that operate at frequencies in excess of the signal frequency.

A typical practical arrangement for a 3-level Maser amplifier is shown in

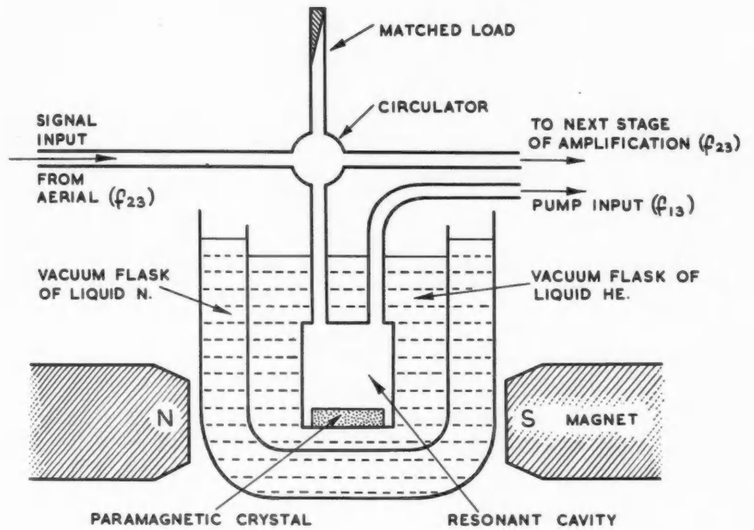


FIG. 5. Diagram of three-level crystal Maser.

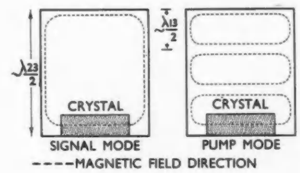


Fig. 5. A paramagnetic crystal is located at the bottom of a cavity resonator which is designed so that it can resonate simultaneously at both frequencies—f_{13} and f_{23}. The magnetic field indicated by the N and S poles of the magnet shown allows some adjustment of the energy level spacing and, hence, of f_{13} and f_{23}. Pump power at the frequency f_{13} is fed into the cavity from an external oscillator, producing saturation in the crystal. The input signal from the aerial, at the frequency f_{23}, travels via a circulator into the cavity, where it is amplified by "stimulated radiation". It then passes on, via the circulator, to the next stage of amplification, which would probably be a conventional microwave tube (for example, a multi-cavity klystron or travelling-wave tube).

The paramagnetic crystals used are usually complex substances; for example, an early three-level Maser utilised a gadolinium ethyl sulphate crystal diluted with lanthanum ethyl sulphate. Various forms of ruby are used most frequently at the present time, however. A typical ruby Maser operated at a temperature of 1·25°K has amplified at a frequency of 2800 Mc/s with a bandwidth of approximately 20 Mc/s, a pump power of 10 milliwatts, and a noise temperature of 20°K. The power output and bandwidth are a function of pump power; the power output can be increased by pumping harder, but the bandwidth narrows down as a result. Since a major source of noise may be the thermal motions in the crystal, operation at liquid helium temperatures (<4°K)—sometimes required by other physical considerations—is obviously desirable. Although the boiling-point of liquid helium at one atmosphere is 4°K, temperatures of the order of 1·25°K have been obtained by decreasing the vapour pressure above the helium reservoir.

The Maser has one of the major advantages of the parametric amplifier; since it draws its power from a pump at a different frequency from that of the signal, little noise is contributed from this source. As with the parametric amplifier, however, noise can originate in any of the resistive components associated with the circuit, such as the circulator, although the operation of these components at a low temperature helps to minimise it. In practical Masers, the noise temperatures are generally higher than the ambient temperatures because all of the resistive noise has not been eliminated.

The use of cavity Masers is rather restricted, since they suffer from a number of disadvantages. As in the parametric amplifiers, the higher the gain the greater the tendency to instability and oscillation. Since the "active medium" of the Maser may be represented as a negative resistance in parallel with the equivalent circuit of the cavity, the usual instability theory appropriate to negative resistance systems applies. Stable gains of 20 db (power gain of 100) or more are quite difficult to achieve and, moreover, the use of a resonant cavity to intensify the interaction fields (for this is the primary purpose of the cavity) means restricted bandwidth; for example, at 20 db gain, the maximum bandwidth is only about 20% of the absorption line-width—about 10 Mc/s. The cavity, moreover, needs accurate, sensitive tuning.

Finally, since power sent through the cavity in either direction is amplified, reflections from waveguide discontinuities tend to cause instabilities. Although these can be minimised by the use of a circulator, this component contributes

(*U.S. Army*)

FIG. 6. Half-inch square synthetic ruby fixed into tip of copper transition section just before insertion between poles of permanent magnet.

(*U.S. Army*)

FIG. 7. A ruby Maser amplifier just before insertion into the liquid helium reservoir at the right.

noise. A device which is intrinsically non-reciprocal (as is the travelling-wave tube, for example) would be preferable.

Although the Masers discussed so far have been useful as narrow-band amplifiers (in the detection of 21-cm. hydrogen radiation in radio-astronomy, for example) and frequency standards, a need was felt for a device that would give stable gain over a wide band. This led research workers to investigate the possibility of a "travelling-wave Maser"—a device using an active medium which interacts with a "travelling wave" rather than a "standing wave"—to be discussed in a later section.

PRACTICAL MASER AMPLIFIERS

The cavity type. The physical appearance of most Maser amplifiers is very different from that of conventional valve amplifiers. At first sight, a Maser would appear to resemble a rather complicated piece of plumbing and, as far as the physical construction is concerned, it is. At very high frequencies, ordinary connecting wires are useless, and even coaxial cables have such high losses that they are very unsatisfactory. In the Maser, signals are conveyed between components along the inside of metal tubes called "waveguides" that are usually rectangular or circular in cross-section, as in Fig. 7.

Although the resonant circuits used in Masers may be represented by an equivalent circuit comprising the familiar inductance, capacitance, and resistance, they are very different in actual construction and appearance from normal components. At centimetre wavelengths, the input circuit is a resonant cavity in the form of a metal box in which the signal travels to and fro from one end to the other. If the cavity is entirely lossless, the input signal injected into it will continue to travel from one end to the other for ever. In practice, however, the losses due to the finite resistance of the metal walls and the losses in the dielectric of the cavity will result in the signal dying away unless power is continually fed into it. In some ways it is similar to an acoustic resonator, but its "Q" factor is very much higher than its acoustic counterpart. (Q is defined as the ratio of the energy stored to the energy lost per cycle.)

A resonant cavity is used for two reasons: (*a*) like any resonant circuit, it only responds strongly to signals at certain frequencies; (*b*) the input signal to a Maser amplifier has to provide a strong electromagnetic field in order to influence the crystal, and a cavity is the most efficient way of doing this.

A very high Q cavity will produce a strong electromagnetic field from a fairly small input signal just as a simple resonant circuit will produce a large voltage or current from a small input signal. Since energy from the pump must also be fed into the crystal, the use of a cavity that is also resonant at the pump frequency makes it possible to produce a fairly large field from a reasonable small amount of pump power. (One must remember that it is

both difficult and expensive to generate a large amount of power at very high frequencies.) Although circuits that resonate at two frequencies are difficult to produce with conventional inductors and capacitors, there is no problem with a microwave cavity, since any metal box will resonate at an infinite number of different frequencies. By carefully choosing the dimensions of the Maser cavity, it can be made to resonate at both the pump and signal frequency, and the electromagnetic field produced by the two sources can be made to interact with the crystal.

Another important feature of the Maser amplifier is the unidirectional device that lets the input signal pass into the waveguide leading to the cavity but lets only the amplified output pass on to the next stage of amplification. These "circulators" are too complicated to be considered here but they look like a rather complex joint between four waveguides. They sometimes incorporate a piece of "ferrite"—one of the few magnetic materials that will operate satisfactorily at very high frequencies. Suffice it to say that if power is fed into arm 1 of the circulator shown in Fig. 8, it will come out of arm 2, while if power is fed into arm 2 it will come out of arm 3. It is easy to see why such devices are called circulators—the power can only travel from one arm to the adjacent arm in one direction.

The pump supply for Maser amplifiers is usually a simple microwave oscillator. Various types are used but their construction and design are not essential to this discussion. Some of the types of amplifiers that have actually been developed and used will now be considered.

There are many possible applications for Masers but so far they have been used mainly by radio-astronomers

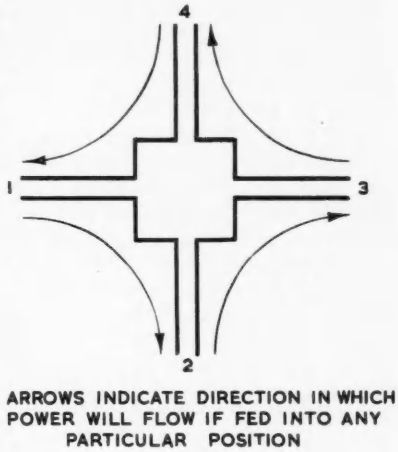


FIG. 8. Schematic diagram of a Circulator.

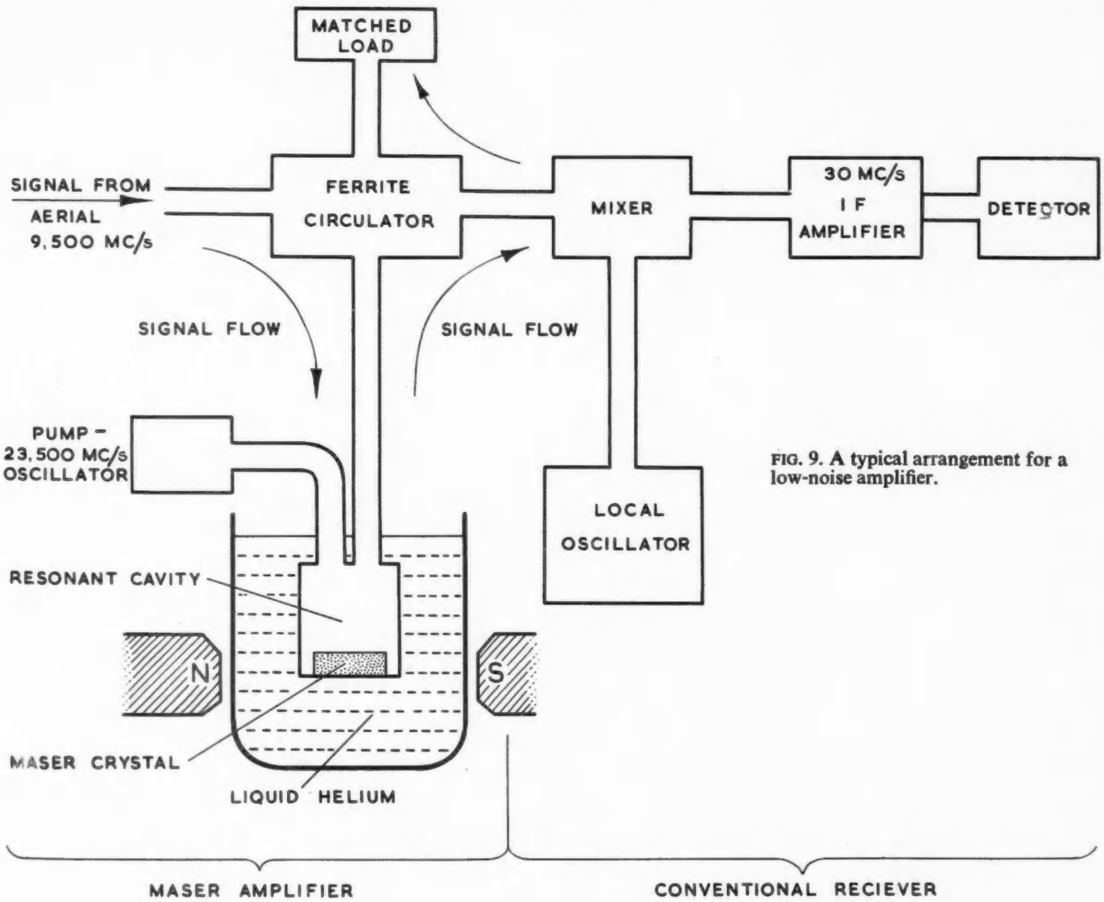


FIG. 9. A typical arrangement for a low-noise amplifier.

for the amplification of extremely faint signals from outer space. These signals are picked up by aerials that are often in the form of parabolic metal dishes of the type used in radar. Although it is very convenient to have the amplifying and receiving apparatus separate from the aerial and connected to it by a waveguide, particularly when the aerial has to be moved, a length of waveguide has finite resistance, and we have already seen that a resistance at anything but absolute zero temperature produces noise. The greater the resistance, the greater the noise. The signals that radio-astronomers are now interested in are so weak they would be masked even by the noise from a length of passive waveguide. As a result, the Maser amplifier has to be mounted on the aerial itself.

A typical arrangement is shown in Fig. 9. As the Maser has to be cooled with liquid helium and the aerial may have to be moved at the same time in order to follow a particular signal source, there are a number of practical difficulties inherent in this arrangement. In a similar system, the total noise of the Maser itself together with the background noise received by the aerial from the sky is equivalent to a temperature of only 85°K or so; if the Maser were placed away from the aerial and connected to it by a waveguide, the waveguide itself would have produced noise equivalent to a temperature of 150°K.

This Maser operated at 9500 Mc/s with a bandwidth of 5·5 Mc/s, which is only about 0·06% of the signal frequency.

The travelling-wave type. The main disadvantage of the cavity resonator is that it will only operate over a very narrow bandwidth. Amplification could be achieved by dispensing with the cavity entirely but the input signal would produce a weaker field if this were done, since there would no longer be a resonant input circuit. This advantage can be offset by using a longer crystal, since an input signal travelling through a crystal for a longer time would have a greater opportunity to extract the energy from it, but a very long crystal would be needed to get a reasonable gain with an ordinary waveguide. If a simple crystal-filled waveguide were used, it would, in fact, have to be 300 cm. long to obtain a useful amount of amplification. Apart from the technical difficulties, such an amplifier would be rather expensive.

If we *slow* the wave down, however, we can achieve the same effect with a shorter length of ruby. In a normal waveguide, the wave travels with a speed close to that of light. By adding a suitable structure to the guide, this velocity can be reduced by a factor of about 100 and a reasonable gain can thus be achieved with a fairly short length of ruby-filled waveguide.

A "slow wave" structure can be made by spacing a number of posts in the guide, the crystal being placed alongside them, as shown in Fig. 10. Power from the pump source is fed into one end of the guide to energise the crystal. The input signal is fed directly on to the slow-wave structure by using one of the posts as a small aerial to launch the wave.

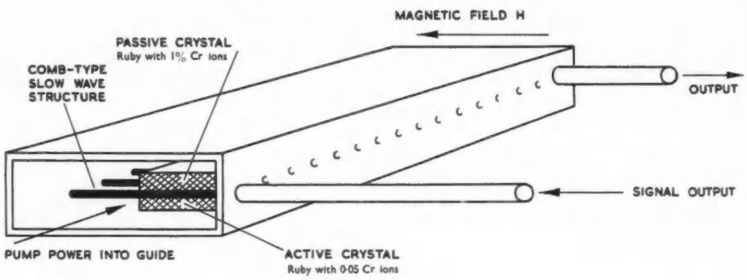


FIG. 10. Travelling-wave Maser with slow-wave structure.

One disadvantage of this simple device is that if any of the amplified power at the output end is reflected back to the input and again reflected, the signal will be amplified further; if the resulting signal continues to be reflected and amplified, the device will burst into oscillation. Reflections always occur at these frequencies unless the transitions between the coaxial cables and the slow-wave structure are extremely well designed. However, it is possible to arrange the slow-wave structure and the crystal so that the device only amplifies strongly for a wave travelling in one direction. The unwanted reflected wave can be reduced by incorporating a piece of differently treated ruby in the system to attenuate waves travelling in the backward direction without affecting those travelling in the forward direction (the principle on which the ferrite circulator used with the cavity Maser is based).

A typical travelling-wave Maser gives 23 db gain at 6000 Mc/s (5 cm. wavelength) and has a bandwidth of 25 Mc/s as compared with the bandwidth of a few Mc/s or less obtained with the cavity-type Maser. The noise temperature of this device is about 10°K. The bandwidth may be increased further by adjusting the magnetic field so that different parts of the Maser crystal are tuned to different frequencies. (This process is similar in principle to the stagger tuning used in receivers at lower frequencies, for example television, to obtain large bandwidths.) The use of this scheme can increase the bandwidth of the above Maser to 67 Mc/s, but at the expense of the gain which would be reduced to 13 db. As with the cavity Maser, the travelling-wave type is usually cooled by immersion in liquid helium.

CONCLUSION

In a field which has expanded as rapidly as that of the low-noise amplifiers considered in these articles, it is difficult to present any summary of the properties of the devices in existence which will remain valid or useful for long. However, a comparison of the properties of parametric amplifiers and Masers which might be of interest to potential users is presented below.

Gain. The gain attainable with either the parametric amplifier or Maser is usually limited by instability; if the device is designed with too high a gain, it is likely to behave as an oscillator rather than an amplifier. The Adler

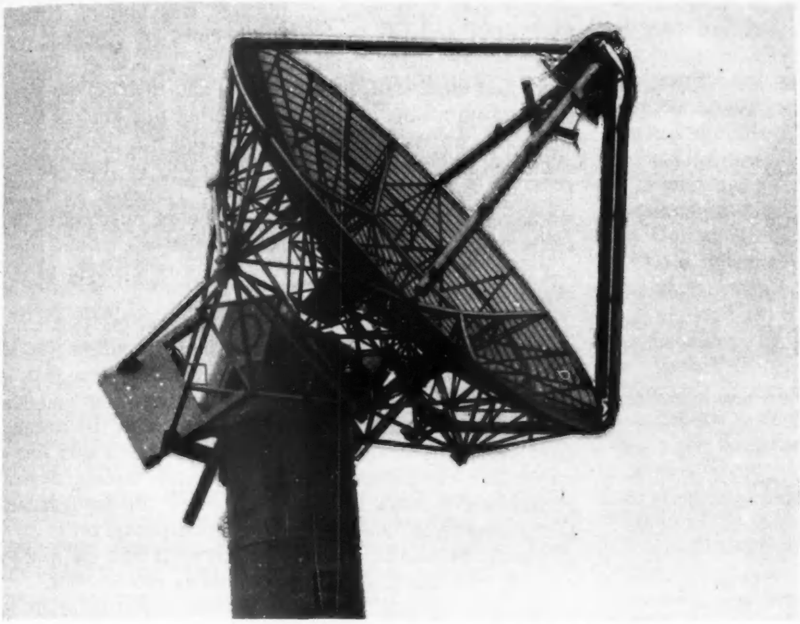


FIG. 11. Maser mounted at the focal point of a typical receiving "dish".

tube described in Part I is, however, inherently stable and the travelling-wave Maser can be made so by careful design. These two devices thus offer, along with the super-regeneratively operated parametric amplifier, the best prospects for high gain.

Bandwidth. This is severely limited in any device employing resonant cavities, although bandwidth can always be increased at the expense of gain. Greatly increased bandwidth can be obtained by using a travelling-wave structure, and the travelling-wave Maser is a most promising device. Since the first part of this article went to press, a travelling-wave parametric amplifier has been produced with a noise figure of 1·2 db and a bandwidth of 500 Mc/s at a frequency of 1700 Mc/s—without the necessity of refrigeration! The emergence of this device as a practical amplifier could be of the greatest importance. It should not be forgotten, however, that the Adler tube is also capable of broadband operation.

Power handling. The power which can be handled by Maser crystals is minutely small. This does not really matter, however, since conventional valves can be used to provide power amplification once the Maser has boosted the level of the weak input signal. Parametric amplifiers can handle much larger powers.

Noise. The lowest noise figures have been produced with Masers, refrigeration reducing the noise to a minimum, although the Adler tube has produced the lowest noise figure of all, so far. For most practical purposes, conventional Masers have satisfactorily low F-values.

Compactness. Parametric amplifiers and Masers both require a fair amount of ancillary equipment (pump sources, and so forth) and these tend to make for bulkiness at present. The liquid helium cooling needed by the Maser is also a severe disadvantage.

Operating frequency. So far, Masers have operated at much higher frequencies than parametric amplifiers. The majority of the former operate at centimetre wavelengths whereas the latter are mainly confined to the 30-cm. to 3-metre range. Parametric amplifiers are limited by the residual reactance of the variable element, but parametric oscillators have operated at 30,000 Mc/s (1 cm. wavelength) using gallium arsenide diodes. Although Masers and parametric amplifiers are both limited by the lack of suitable high-frequency pump sources, there is no fundamental limit to the frequency at which Masers can be made to operate and, in fact, the principles described in the three-level Maser section have recently been used to make an amplifier for visible light—the "Laser".

Which of the limitations listed above is important to the user is determined, of course, by the application envisaged. The communication engineer who wants a low-noise repeater system for an artificial satellite telephone link would have trouble providing liquid helium cooling for a Maser. In fact, neither the parametric amplifier nor the Maser are too well suited to satellite flying because of the bulk of the auxiliary equipment involved, even though their low-noise properties are ideal. The communication engineer is also concerned with the bandwidth problem, but the Adler tube, travelling-wave Maser, or even a carefully made Mavar could provide useful bandwidth for many applications.

The radio-astronomer, on the other hand, requires extreme stability in the devices he uses, since the noise temperature of the stars he is surveying are several orders of magnitude below that of his receiving system. If the noise in his receiver is constant and the gain is stable, the star can be detected as a change in the mean noise level. This stability requirement makes the Adler tube most suitable for his purposes. Much work has been carried out in recent years on mapping the hydrogen clouds which fill regions of cosmic space, and since this hydrogen radiates at a wavelength of 21 cm., it is difficult to envisage a better amplifier for this purpose than a Maser. Great bandwidth is not required here and a cavity device like the one described in the preceding section is quite suitable.

The most intriguing possibility is suggested by the light-frequency Laser. If intelligence could be transmitted at light frequencies (of the order of mega-megacycles), the bandwidth available to the communication engineer would be enormous. It needs only a cursory examination of the already overcrowded radio spectrum to indicate the importance of this. In a world where communication between all points is increasing at an unprecedented rate, the need for more bandwidth is critically urgent. The recent invention of an amplifier that works at the frequency of light may be the answer to this problem.

HOW MUCH

HOW MANY

WHAT SORT

RITCHIE CALDER

Despite the prejudices many business men still have against scientists and engineers, the demand for them continues to grow and will continue to run ahead of the supply during the foreseeable future. Britain's future depends on the production of a surplus for export. This article is the fourth in a series by journalist Ritchie Calder on the role of science in industry.

The chairman of a large company that relied on science rather than the industrial arts was complaining one day about "those scientist chaps". His prejudice was clearly evident. He himself had "come up from the factory floor" and believed that experience was worth more than experiment. An eminently successful business man, he could make use of the results of science without concerning himself unduly with how they had been achieved in the laboratory.

"There are two scientists on the board and that's two too many," he said sourly. They were working directors—heads of the research and development departments—and they spent a "great deal of money" (actually about 2% of the turnover). The burden of his complaint was that "scientists had no business sense". He accused them of over-indulging in what he called "stop-press science", continually modifying their ideas with new facts. Always looking over the horizon, they did not know when to "freeze" research into production. Thus, while the production director was clamouring to get Mark II on the line and the sales director suspected their competitors were working on Mark III, the research director was holding out for Mark IV. Furthermore, the directors of research and development were "empire builders", always wanting more and more staff, with honours, and their fellow directors had no means of assessing whether this kind of talent was really necessary. Another complaint was that scientists could not really explain the what and why to "hard-headed business men"—they talked jargon. Thinking aloud, he wondered whether it would not be better business to buy science "off the peg" like a ready-made suit so one could see what one was getting. Wouldn't it be cheaper to buy "know-how" than develop it?

Manifestly, his strictures were unfair and his generalisations far from justified. There are many scientists who sit on boards of directors (more in the United States than in Britain) who are extremely shrewd business men and who are perfectly capable of arbitrating the claims of research directors or "freezing" research for the production line—even when they suspect that their scientific colleagues may be right about Mark IV. This chairman's attitude is important, however, for his is a highly successful and progressive company. Moreover, the same kinds of things are said by other industrialists, although with more moderation.

Another attitude of business men towards scientists found an echo in the report of the Oxford University Appointments Committee. The Committee pointed out that industry would look elsewhere for recruits if the universities did not turn out science graduates who were capable of handling men. The report referred to "the dreary procession of would-be B.Sc's whom the industrial recruiters see every year" and said the typical graduate was becoming "a memoriser and regurgitator of stored facts". With the universities and colleges being expanded to produce more scientists, technologists, and technicians—the specialists for whom industry is supposed to be looking—business men in the bow-edge of advancing industries are now getting worried about "over-specialisation" which, in the name of change, is becoming ill-adapted to change. "Sewn-up minds which we have to unstitch" was the phrase of one enlightened industrialist who preferred school-leavers to college graduates because they were more pliable and adaptable.

Another matter over which directors (including those in charge of research) express concern is the ageing of research scientists. "Ageing" is very much a relative term. Companies will willingly engage, as consultants, eminent scientists who have retired from academic life. But, they will tell you, the flint-and-tinder period in which ideas spark creative research is the twenties and early thirties. A flow of young graduates is considered essential, but industry does not know how to siphon off the older research workers. In this context, "older" means over 35 or 40, for it is at this age, as one research director put it, that new ideas begin to be met with the statement "We tried it once and it did not work." Although a researcher may have gained considerable experience in his field when he reaches this age level, he often becomes little more than an expensive laboratory technician (or so it is implied) unless he can lead a group or head a department. In any large industrial concern, there is usually ample opportunity for promotion,

but it is away from the laboratory and into management and the research man cannot adapt himself to such a move —so the litany goes—because of his training and set ways. He is poor in public relations and inarticulate in his approach to problems outside his own field.

These are harsh arbitrary judgments and it is rare that responsible companies apply them, but it is what they talk about and it bears on the contradictory attitude of industry to the educational problem. Qualifications are measured by degrees and the "talent scouts" seek out the likely first-class honours graduates for well-paid jobs. Having hired them for specialised positions, however, they then complain that they are over-specialised and want to turn the introverts of research into extraverts of management.

A LUMP OF COAL SURROUNDED BY FISH

The dilemma is becoming exaggerated and aggravated by the inescapable need to produce more scientists, more technologists, and more college-trained technicians. It is inescapable because the future of Britain depends upon the availability of scientific and engineering manpower. Aneurin Bevan once described Britain as "a lump of coal entirely surrounded by fish" and, indeed, coal is the only indigenous natural asset apart from brains and skills. Since we have to import about nine-tenths of our materials for industry, we can afford to pay for them and the 50% of our food supply that we import only by enhancing the value of these materials with our scientific and technological skills.

Britain, with a run-away advantage in the first industrial revolution, could mechanise illiterate crafts and mass-produce consumer goods, dominate the markets, and prosper. But the Great Exhibition of 1851, which is generally thought of as the triumphal boast of British achievement, already showed to the discerning that Britain had something to learn from other countries. By 1867, the year of the Paris Exhibition, Britain excelled in only ten of the ninety departments. Although prosperous complacency continued to prevail, it was obvious by the end of the century that Britain, the pace-maker, was being outstripped—not because of any backwardness in science but through the lack of application. The reasons were quite plain. Technological know-how was looked upon as something to be learned on the job, not in the classroom. In other countries it was different. The French Ecole Polytechnique of the immediate post-revolutionary period set the example for higher technical institutions in Germany, France, Switzerland, and America. The first country to challenge the British monopoly was Belgium where King Leopold, well informed about British industry, first established communal schools, then set up technical schools, and then introduced British machinery. Other countries also used educational springboards to vault ahead. Although there was no federal system of education in the United States, over 500 technical institutions of varied pattern were in existence by 1900. The Massachusetts Institute of Technology, founded in 1861, offered thirteen distinct four-year courses to applicants who could pass the initial examination. Industry activities supported such colleges everywhere in the U.S.

In Switzerland, the Federal Technische Hochschule of Zurich, founded in 1885, awarded diplomas which ranked as university degrees. This tiny country, practically bereft of industrial raw materials, imported them and added an increment of value with their brains and skills. In Germany, the greatest academic scientists in the country made room in their classes and laboratories for industrial candidates. Basic and applied science were respectable room-mates and technology benefited from the contact.

During the 19th century, Britain lost Perkin's synthetic dyestuffs to Germany and Bessemer's blast furnaces to the United States (for all practical purposes). The saying "Britain invents and foreigners apply" was quoted as though it were a boast instead of a confession.

Technical education in this country actually began with the artisans rather than the industrialists. When Dr George Birkbeck took up the chair of Natural Philosophy and Chemistry at Anderson College, Glasgow in 1799, he was so surprised to find the workmen interested in the apparatus they were installing in the laboratories, he invited them to a special mechanics' class. By the fourth meeting, the attendance had risen to 500. When he moved to London, Dr Birkbeck continued holding such classes and eventually started Birkbeck College. Similar institutes sprang up in provincial centres at such a rate, there were 600 with a membership of over 100,000 by 1850.

Britain's "Charlottenburg" began modestly and belatedly with the founding of the Royal College of Chemistry in 1845 and the School of Mines in 1851 (sixty-odd years after the founding of the Technische Hochshule in Switzerland) and, despite the warnings of successive royal commissions, was not consolidated as Imperial College until 1907. It took another 50 years and a near-panic for Imperial College and the other technological colleges to secure the finances and recognition needed for Britain to survive as a leading industrial nation. The situation even now is not reassuring. This country has not yet fully learned the historical lessons of its own shortcomings. It lost the advantage of its industrial headway in the middle of the last century because other countries were recruiting their cadres of technologists from a system of universal education which England did not have until 1872.

The dilemma is inherited and inherent. It needed the visit of British scientists to Russia, and Churchill's "sombre warning" that the East was outstripping the West by its harvest of scientists and technologists, to make the responsible people take note. But a "crash programme" is no substitute for a fundamental reappraisal.

THE PATTERN OF EMPLOYMENT

Answers to the questions *how much, how many,* and *what sort,* have been sought by the Committee on Scientific Manpower of the Government's Advisory Council on Scientific Policy. In 1957, the Council tried to prepare a scientific manpower budget. Apart from obtaining the first approximation to a census (119,700 scientists and engineers), it asked employers to forecast their requirements for 1959. The forecast was 152,200 which, as the 1960 White Paper showed, proved to be 9000 less than the number actually employed in that year. If the manufacturing industrialists had been able to fill their vacancies, the forecast would have been exceeded by an even greater amount. Even with the

shortage, the number of scientists and engineers employed in this one sector in 1959 was 30% higher than in 1956.

The 1957 to 1959 increase occurred mostly in those industries whose output went up during the three years. Some may say that they were prosperous because they employed scientists and engineers; others may say that they could afford to employ scientists and engineers because they were prosperous. It is highly significant that the increase took place in the new industries and not in the older ones which could have afforded the graduates just as well. Was this lack of initiative or was it that the older industries were less attractive? Perhaps scientists and engineers prefer to regard themselves as obstetricians rather than geriatricians; yet it is probably the traditional industries which need the injection of research and development the most.

The building and contracting industries employed just over 3800 scientists and engineers in 1956 and "indented" for 4950 as the need for 1959, an increase of 1150 or 30%. The actual increase was only 9% and they expect to employ only 800 more by 1962.

In the chemical and allied trades, the actual increase was 45% although the estimate had been only 20%; in "other plant and machinery", the increase was 51% instead of the 38% forecast. The recruitment fell below the forecasts in electrical engineering and motor vehicles. The picture is complicated by shortage in some fields. Although the total supply of scientists did not fall short in the 1956 forecast of requirements the chemists were short by 1500 (24,300 instead of 25,800) and the mathematicians were short by 1000 (13,000 instead of 14,000). The shortage of engineers, particularly civil and electrical, proved greater than the shortage of scientists.

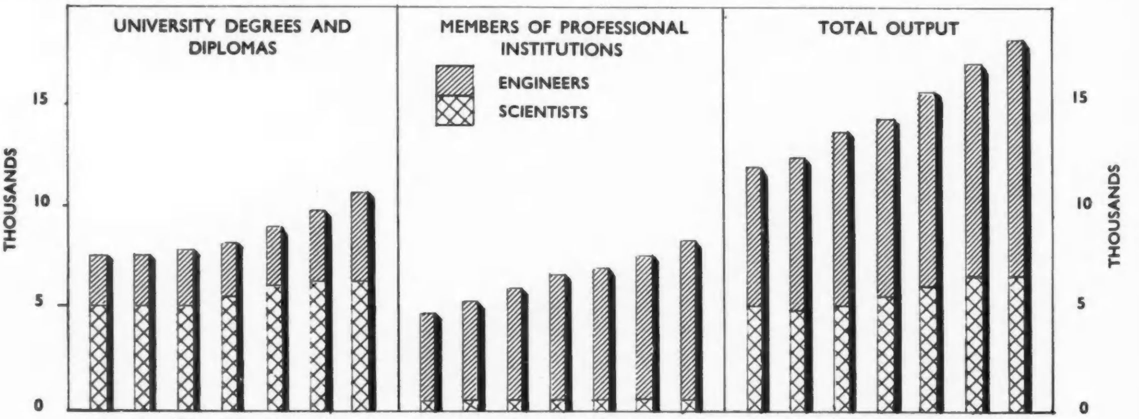
The supply of biologists, on the other hand, went up surprisingly—the number employed in 1959 was 25% more than anticipated. This is interesting because students who were inclined to biology in 1956 were warned that the prospects were not good. Why, in spite of the warnings, did the number of honours degrees in biology increase by 22% during this period—a definite shift in relation to the other disciplines? One can only speculate, but it may have been due to the fact that over 66% of all biologists are employed in education. Due to the shortage of good physics and chemistry masters, "science" in some schools tends to become biology, and a good biology teacher would naturally influence pupils into the subject.

Twenty-five per cent of the qualified biologists found employment in government (Agricultural and Medical Research Councils, mainly) but there was an increased demand from manufacturing industries. Again, why? The Advisory Council suggested that they were employed in other capacities—as production chemists, for example. "Other capacities" can mean a great deal more, however. One industrialist said his firm found biologists "more amenable", meaning they were "more adaptable". They had, he recognised, a proper training in the scientific method but were more accustomed to dealing with variables and to accepting the fact that business, with its human factors, does not function with decimal precision. (This, of course, was the experience during the war when the services discovered the value of biologists in operational research, even when it concerned mechanical problems in which they had no training.) What this suggests is that biology is a likely foundation for a business career.

FROM ARTISAN SKILLS TO GRADUATE BRAINS

An interesting index of the nature of an industry is the proportion of scientists and engineers to the total number of workers in that industry. In electrical engineering, they comprise 2·2% of the total; in chemicals and allied trades they make up 3·7%; in aircraft, 2·7%; and in mineral oil refining, 7·0%. In the motor industry, on the other hand, they are only 0·5% of the total and in shipbuilding, only 0·6%. In private manufacturing industries, as a whole, the proportion of qualified scientists and engineers to the total number of persons employed increased in three years from

Annual output of scientists and engineers in Great Britain.



0·8 to 1·1%. The increased ratio was due not only to the increase of scientists and engineers but also to the quarter of a million decrease in the total. The industries appeared to be turning from artisan skills to graduate brains. If this is a trend, as it almost certainly seems to be, the nature of British industry is changing very drastically and that Chairman of the Board already quoted had better recognise that graduate scientists and engineers are not a luxury but an imperative necessity. One important fact which emerges from the Government survey was that less than half of the scientists and engineers engaged in industry were being used on research and development—evidence that industry finds degrees useful outside the laboratory.

Manufacturing industries employed 44·4% of the 161,000 qualified scientists and engineers working in Britain. In 1959, Nationalised industries, the Atomic Energy Authority, and the B.B.C. utilised 20,700. Government Departments (Defence Department, civil departments, and research councils) had 15,800. With only 32,000 in education, there was a serious shortage in the colleges and schools, although the universities reached their forecast requirement. Industrial research associations employed 1500 scientists and engineers and local authorities had 6900, but both failed to recruit their predicted numbers. Defence work in all fields, including the armed forces, accounted for 20,000.

During the three years between the first and second surveys, 41,000 scientists and engineers qualified. These included 23,500 graduates and 17,500 who were accepted as members of professional institutions, either by way of Associationship, Higher National Diploma (full-time courses lasting three years), or Higher National Certificate (part-time courses lasting at least five years). Allowing for overseas trainees who took their qualifications back home and the British who emigrated, those who became available during this period numbered about 37,700, but the wastage through death, retirement, and the like was about 12,000. A serious loss of quality and potential leadership has resulted from the fellowships offered by America, for over 40% of the fellows have found employment there. The Department of Scientific and Industrial Research is now trying to overcome this by offering return fellowships to Britons in the United States.

The subsequent three-year period, 1959 to 1961, is expected to bring about 51,650 new scientists and engineers as a result of university expansion and the major reorganisation of technical colleges. Although this is a significant increase, it is still 5600 less than the number that will be needed by 1962, according to the last forecast. The actual shortage will probably be worse because it was apparent that the employers, in filling out their returns, were not estimating what they wanted but what they were likely to get. The best that can be hoped for, at this point, is that Britain will have an annual output of 20,000 graduates, or their equivalent, somewhere about 1965.

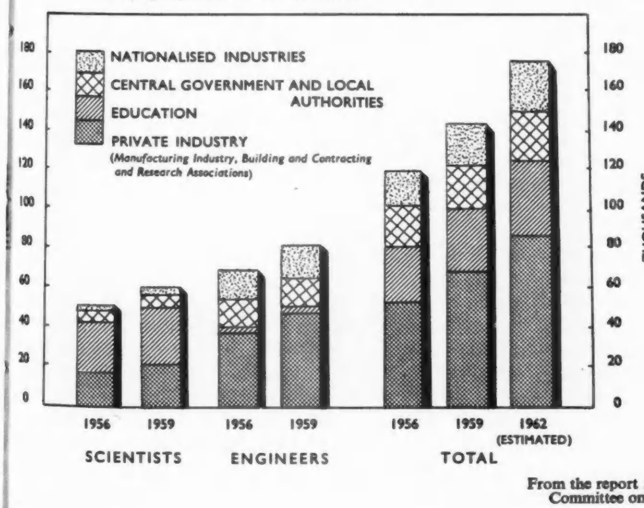
This is an improvement, but is it good enough?

RAW MATERIALS, MARKETS AND FOOD

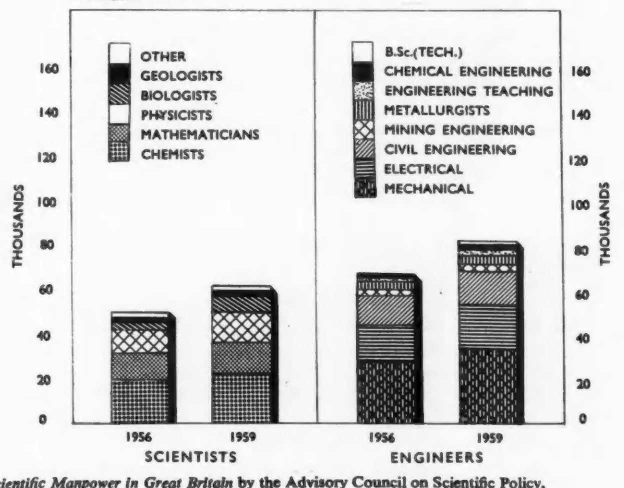
There is not much "slack" to allow for what many enlightened industrialists now regard as essential—the provision of qualified people for work overseas. It is apparent that competition in the future will lie not only in the export of goods but also of services—the export of experts—which will make it possible for countries to avail themselves of our goods. Call it "technical assistance", "technical cooperation", or "mutual aid", but what it means in terms of enlightened self-interest is the ensuring of markets for producer and consumer goods and the securing of access in developing countries to the raw materials and food which Britain must have. Some far-seeing concerns have recognised this and see to it that their experts spend several years in "field work" abroad before settling down in the organisations at home.

How much, how many, and what sort, are questions which require a great more thought by educationalists and industrialists alike if Britain is to maintain its position in the world.

Distribution of scientists and engineers in the main fields of employment in Great Britain.



Distribution of scientists and engineers by profession in Great Britain.



From the report *Scientific Manpower in Great Britain* by the Advisory Council on Scientific Policy, Committee on Scientific Manpower—by permission of the Controller of H.M. Stationery Office.

THE BOOKSHELF

Under the Deep Oceans

By T. F. Gaskell (*Eyre & Spottiswoode, 1960, 240 pp., 8 figures, 25s.*)

The key to some of the big questions of earth history will be found beneath the floors of the oceans. The necessary work calls for money, ingenuity, and often a disregard for personal comfort; the ocean floors, consequently, have remained the least known parts of the earth's surface.

A good account of a team and the task it faced on one round-the-world cruise, which commenced in 1950 and lasted 2½ years, has been given by Captain G. S. Ritchie in "Challenger, The Life of a Survey Ship" (Hollis & Carter, 1957). Now Dr Gaskell gives a lucid account of the seismic prospecting which he and Dr J. C. Swallow carried out on that cruise and gives some impressions of the out-of-the-way ports at which they called. The scientific results are clothed with what is known or surmised about the structure of the ocean floors, and some attention is paid to most branches of oceanography.

Beneath the oceans, tremendous forces are at work forming mountain chains and deep trenches, and moving continents about. Although the forces act slowly there are volcanoes and earthquakes to remind us of their operation. Meanwhile a history of these changes, and of the sea itself, is being recorded in the pile of sediments which is accumulating in vast hollows of the rock floor. So far only the surface of this fascinating record has been scratched, but there seems no reason, other than shortage of money, why the whole of it should not be sampled.

Dr Gaskell's enthusiasm and clear style should do something to increase interest in the sea and the floor beneath it. But it is a pity that there is neither a map showing the place-names mentioned in the text nor a glossary of technical terms, some of which will be unfamiliar to the layman.

A. H. STRIDE

The Nature of the Chemical Bond
(Third Edition)

By Linus Pauling (*Cornell University Press, 1960, xx+644 pp., 60s.*)

There are probably very few chemists who do not possess or at least have not read "The Nature of the Chemical Bond". Indeed, it is doubtful if any other chemistry book published during the last fifty years has produced a greater impact and impression on chemical thinking, and Pauling's views of structural chemistry and his approach to structural problems have been a source of enlightenment and stimulation for countless students over the past twenty years. As one of those students, it grieves me to have to write that Professor Pauling should have let his classic be.

In what the sub-title calls "An Introduction to Modern Structural Chemistry" one might have hoped at this time for considerably more than the second edition merely revised and to some extent brought up to date with a little additional material. It is certainly true, as Professor Pauling notes in his preface, that it is not possible in a short book to discuss all of the present knowledge of molecules and crystals, and it is reasonable that we should be content with the presentation of general principles. But it is on the latter score that this new edition is most disappointing. Whilst some useful additions have been made, for example, electronic structures, energy levels, etc., the general treatment is still basically along the valence-bond approach of the original editions. Although the molecular-orbital approach is not a panacea, it deserves at least discussion as an equally valid approach to many valence problems, but the earnest efforts of a number of theoretical workers over the past two decades are barely noted.

As an example we can use an area where Pauling's views used to prevail exclusively and in which he has made significant contributions, namely the problems of complex compounds and their magnetic complexes. Here we now find hardly a mention of the ligand-field developments, which, though quite old, have been so successfully exploited during the past few years in the interpretation of spectral, magnetic, and other data. Pauling's treatment here has hardly changed, and inventing the confusing terms "hypoligated" and "hyperligated" in place of "essentially ionic" and "essentially covalent" begs the issue—we are still asked to swallow interpretations requiring a ligand to be "hyperligating" towards one metal whilst being "hypoligating" towards another of similar character and electronegativity. In this section, as in other places in the book, one cannot escape the feeling that Prof. Pauling has not changed his views for twenty years. This suspicion is heightened by his views on boranes and other non-classically bonded compounds such as ferrocene, in which only a valence-bond approach is discussed. A further suspicion that arises also occasionally is that he can explain anything, even where, as on p. 390, he has his facts wrong ($C_{10}H_{10}Ti$ is diamagnetic).

In spite of the disappointment on the overall discussion of chemical bonding this book can nevertheless be recommended to students and others, not least because it is a very personal sort of book reflecting Pauling's views. There are many references and data, and although in some sections the selection of material is somewhat arbitrary and not up to date, it is still a useful and stimulating book. However, it does need to be remembered that Pauling's way of looking at problems is not the only one or even the best one.

G. WILKINSON

Radioactive Wastes, Their Treatment and Disposal

General Editor: John C. Collins (*E. & F. N. Spon Ltd, London, 1960, 239 pp., 55s.*)

Sir Alexander Fleck points out in the foreword to "Radioactive Wastes" that progress in the field of nuclear energy can only be maintained as long as ancillary technologies progress at a similar rate. One of the more important problems arising in the development of nuclear power on the scale to which this country is committed, is that of handling and disposing of the radioactive by-products which are an unavoidable concomitant of nuclear fission. These wastes may be solid, liquid or gaseous and the disposal of each raises its own special problems.

This book deals with all aspects of this new technology and naturally enough draws heavily on the experience of the United Kingdom Atomic Energy Authority in whose reactors most of this waste arises. The sections dealing with the practical side of treatment and disposal are written by Authority or ex-Authority staff who describe very fully the current techniques and possible future developments in this field. In addition there are some general chapters which describe the nature, measurement and hazards of radioactivity. The complexity of the subject is exemplified by the variety of disciplines involved, which include various aspects of biology, chemistry, physics, electronics and meteorology. It is extremely useful to have all this diverse material drawn together

into one volume and "Radioactive Wastes" will be a valuable source-book to people working in the field of Radiological Health and a guide to all users of radioactive materials.

As the recommendations of the International Commission on Radiological Protection provide the foundations for the science of radiological safety, it is a pity that publication could not have been delayed for a short time so as to include the recently revised values. It is only fair to point out, however, that wherever the old values are quoted, the reader's attention is drawn to the fact that a revision is expected. As is inevitable with a complication of this type with different authors writing on related topics, there is some duplication of material, but this appears to have been kept to a minimum and does not in any way detract from the value of this book. A. MORGAN

Moon Maps

By H. P. Wilkins (*London, Faber & Faber, 1960, 30s.*)

The large map of the Moon drawn by the late H. P. Wilkins has achieved wide recognition. It has now been re-issued in twenty-seven sections, with a brief description of each named formation on the lunar surface. The maps are excellently produced, and conveniently bound in loose-leaf form. A final revision was carried out by Wilkins shortly before his death in January 1960, and there is also a preliminary chart of the features on the averted hemisphere, based on photographs sent back by the Russian space-probe *Lunik III*. P. MOORE

Instinctive Living: A Study of Invertebrate Behaviour

By Theodore Savory (*Pergamon Press, 90 pp., 17s. 6d.*)

The key to the author's motive in writing this book is perhaps his statement that study of behaviour of animals is most fascinating and "transcends all other branches of Zoology". He loves his animals and loves watching and wondering what they will do next; as with other love-objects, there is a danger that fascination might introduce some loss of objectivity. In this case, there is a reluctance to accept that his fascinating creatures might be so ordinary as to obey the laws of physics and chemistry. While the descriptive matter of the book presents clear and interesting accounts of the behaviour of spiders and other invertebrates, much of the book is taken up with philosophical discussion urging that mind is not a function of the brain, and that animals are not machines. Plants are "nothing more than physico-chemical systems", he says, but animals are not, for they have minds which "make ordinary physics and chemistry inadequate". He disposes of the proposition that "the mind is a part of, or a function of, the brain" with the help of a quotation, of dubious logic, from C. E. M. Joad, which could equally well "prove" that computing machines could not compute!

If the animal is purely a machine, he says, it should "always respond to the same stimulus in the same way". Such fallacious and old-fashioned statements make it clear that, though the author flirts with cybernetics for half a page (mainly to define it inadequately and to wonder at it), he has by no means appreciated or assimilated modern ideas on behaviour or on machines. Feedback is not mentioned at all; nor is the possibility that a machine may alter the instructions to itself as a result of its experience and so behave differently to the same stimulus, just as animals do. As W. Ross Ashby* points out: "All that is needed for goal-seeking flexibility is negative feedback", whether it is a guided missile or an animal which is seeking its goal, which may then be reached by many different paths. Savory's descriptions of the behaviour of spiders in their webs are not inconsistent with the operation of such a mechanism. So zealous is the author in denying the function of mind to the brain that he even by-passes the nervous system altogether in his explanation of a moth's attraction to a candle—substances produced photochemically in the eyes are supposed to *diffuse* through the body and affect the flight muscles unequally until the animal turns towards the light!

At times the author opposes organised science, deploring the biochemists and their doctrines, and the physiologists in their "austere" laboratories who, he supposes, deny that an animal is a sentient being. The animal, he says, is a "psychosome", a mysterious union of mind and body. While the author does not invoke the deity in support of his philosophy, one feels all through the book that he is on the point of doing so.

This book is written mainly with the heart rather than the head. It is more suitable as reading matter for kindly old ladies than for someone who really wants to know what makes animals behave as they do.

It is to be hoped that it is not the policy of the distinguished zoological editors of this International Series of Monographs on Pure and Applied Biology to encourage mystical views on animal behaviour.

R. J. GOLDACRE

* Ashby, W. Ross (1954). "Design for a Brain", Chapman and Hall.

The Orchids: A Scientific Survey

Edited by Carl L. Withner (*New York, The Roland Press Company, $14*)

Orchids, as Carl Withner's introductory chapter to this book shows, have attracted man for at least 2500 years, but it is only within the last century or so that the plants producing them have been scientifically studied.

The present volume, which is one of the *Chronica Botanica* Plant Science Series, is in effect a symposium on the scientific and botanical (rather than the horticultural) aspects of orchidology, a subject to which attention has especially been drawn by the holding of the World Orchid Conference in London this year . . . a meeting which was, indeed, much more of a scientific event than a jamboree for the growers (let alone the wearers) of these gorgeous and fascinating flowers. It is for the view it gives of this scientific background that this book will appeal to the general reader interested in botany, who will find several of the chapters decidedly thought provoking as well as informative.

Typical of these is Helen Adams's essay on "Aspects of Variation in the Orchidaceae", in which she draws attention to some of the inconsistencies in the division of the orchid family into the Diandrae and the Monandrae on the basis of the morphology of the male organs. In place of this, the possibility of a classification based on "inherited growth patterns" is discussed . . . to be established, it would appear, partly from a study of cultivated varieties and hybrids. The sixty-one very attractive black and white plates included in this chapter are, perhaps, as valuable in supporting the author's argument as the text.

Embryology, cytology, and genetics of the orchids each have a chapter on their own, while another study of great interest to the general reader is that of Prof. Hans Burgeff of Würzburg University (the only contributor from outside America) on mycorrhiza. This is also virtually the only chapter in which material is based, to a considerable extent, on experiments with terrestrial European species, namely *Orchis mascula* and *O. militaris*. Other chapters deal with photoperiodicity in orchids, and the fungal, bacterial, virus, and insect diseases and pests which attack them, chiefly in the cultivated state.

Finally, there is a chapter on Vanilla, "the orchid of commerce", which is followed by appendices, of which the most interesting is that consisting of a key to the families and genera by Charles Schweinfurth based on that originated by R. Schlechter in 1926. Students of our own orchid flora will note that he considers such genera as *Gymnadenia*, *Coeloglossum*, and *Platanthera* (our fragrant, frog and butterfly orchids) as merely sections of the much larger genus *Habenaria*, on the grounds that they are "founded on obscure or recondite characters and are scarcely recognisable when cosmopolitan areas are considered".

In the appendix on chromosome numbers, on the other hand, the opposite tendency is followed, so that the genus *Orchis* is divided into *Orchis* proper and *Dactylorchis*, while the other genera named above are preserved, as is more usual in this country.

For those who will doubtless be inspired by this year's Conference to try their own hand at growing orchids, albeit in the modest fashion which any normal income entails, there is a third appendix on culture media and nutrient solutions, to round off this interesting and authoritative collection.

P. B. COLLINS

"The Pirotechnica of Vannoccio Biringuccio"

Translated by C. S. Smith and M. T. Gnudi from the original Italian edition of 1540 (*New York Basic Books, $8.50*)

There is a new interest in the history of technology, in part aroused by the handsome five-volume History of Technology (edited by Singer and others) recently completed, and this has called for a new edition of "Pyrotechnia", one of the three great metallurgical treatises of the 16th century. The others were De Re Metallica 1556 by Agricola (translated by Hoover in 1911) and the Treatise on Ores and Assaying by Ercker 1574 (translated by Smith and Gnudi 1948). All three were well known and much used in their day and later, but were not available in English until this century, probably because England was poor in metallic ores.

Biringuccio writes as a plain craftsman, "I have no knowledge", he says, "other than that gained through mine own eyes" and he has a down-to-earth common sense that will have nothing to do with finding divining metals by the rod or with transmuting base metals into gold. He knew that smelting the ore should give a yield comparable with the laboratory test on a sample and says "weigh everything, trust no one but yourself". A true scientist, he must have been one of the first to put down in writing that to find the best way you must repeat the process (in the laboratory or smelting works) again and again, varying the procedure a little each time and stopping at the best. Practical writers like him accumulated the experimental facts on which later and more educated men like Boyle built their theories.

In the 16th century, if you were a prospector, miner or worker in metals you had to find a patron, someone to finance you, who, for greed or glory, kept you going until the ore was mined, smelted and made into guns, bells, or statues. Biringuccio worked for a noble family of his native Siena, for the reigning Pope and for the Venetian Republic. He describes the discovery of ores, siting and starting a mine, smelting and casting bells and guns: on the latter he writes with evident knowledge and enthusiasm. He deters the amateur with accounts of the difficulties, but says, "with all this it is a profitable and skilful art and in large part delightful". He probably wrote his book with the idea of attracting men with money to the metal business which, he tells them, is safer than war!

This is a big book, nearly 500 pages, well printed and easy to handle. It has the original illustrations, not very good ones but authentic, and one would not be without them. Here we see the contemporary methods of making furnaces, moulds for guns and bells, of operating furnaces and boring guns, of drawing wire and such war-like occupations as making gunpowder and mining under fortifications. Prof. Smith in his introduction notes that Biringucchio "shares the perplexity of modern man when he sees how scientific knowledge can be used for good or ill and wonders if men make inventions in the desire to serve mankind or from some inner or outer necessity". A. D. CUMMINGS

The Story of Eyes

By S. Sutton-Vane. Illustrated by Anthony Raielli (*London, Phoenix House, 1960, 173 pp., 12s. 6d.*)

This is one of those books the assessment of which depends entirely on the audience for which it is intended. It is written by a "layman" suddenly become curious about the why and wherefore of vision—a subject about which her "ignorance was abysmal". At first bewildered by the technicalities of the subject, she read about it and talked about it and then wrote the story of the development of vision from its most primitive beginnings to what she conceives may eventually be the visual organ of the spaceman—one "Cyclopean orb placed in the middle of his face" provided with two foveae formed by the merging of his present two eyes into one.

The development of visual perceptions from the sensitivity to light acquired by undifferentiated protoplasm is, of course, a fascinating story in which, if it is to be told factually and responsibly, there are many blanks. It is a story that has obviously impressed the author, for she maintains a child-like wonder from beginning to end which is apt to pall on the reader for, after all, the evolution of anything in the universe is similarly full of material for marvel. The book is obviously written for Mr Mits (Man in the Street); and he should enjoy it. We are told, for example, of a calm and rainy night when a fish rested as though suspended by a thread from the full moon, seemingly awaiting a miracle; "Nature poured the miracle of chemical porphyropsin into the rods. . . . Then one of the most wonderful days in the history of eyes dawned in a soft line of luminous grey above the horizon. . . . Suddenly, in a glorious burst of light, the sun rose above the water, and the fish knew its miracle."

In its essentials the story is correct and it would be somewhat out of place to carp at some of the statements with which many would quarrel—that the beginnings of the nervous system appeared first in such animals as the lancelet, or that man is becoming progressively more myopic as a direct result of modern conditions, particularly amongst city dwellers, being limited to looking not much farther than across a room or street. To the uncritical and to those who can digest the sustained narrative of facts in the fanciful terms of poetry, the book will provide an interesting account of one of the most fascinating aspects of the evolution. S. DUKE-ELDER

COMING EVENTS

JANUARY

10–11 Bristol University
Conference on Physics of Polymers
Organising Secretary, The Physical Society, 1 Lowther Gardens, London, S.W.7

16–20 London
45th Annual Exhibition of the Physical Society
The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7

17–19 Louis, U.S.A.
Instrument-Automation Conferences and Exhibits. Instrument Society of America
The Executive Director, Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22, Pennsylvania

FEBRUARY

6–10 Auckland
Annual World Meeting of the British Medical Association
Honorary Secretary, British Medical Association, P.O. Box 3532, Auckland, New Zealand

MARCH

6–9 London
13th Technical Exhibition of Oil and Colour Chemists' Association
General Secretary, Oil and Colour Chemists' Association, Wax Chandlers Hall, Gresham Street, London, E.C.2

15–17 Cologne
International Congress on Medical Photography and Cinematography
Deutsche Gesellschaft für Photographie, Neumarkt 49, Cologne, Germany

21–25 London
10th Electrical Engineers (A.S.E.E.) Exhibition
Electrical Engineers (A.S.E.E.) Exhibition Ltd., 6 Museum Street, London, W.C.1

APRIL

6–9 London
The Auto Fair
Auto Fairs Ltd, 22 Orchard Street, London, W.1

10–15 London
1st International Congress on Metallic Corrosion
Lt-Col Francis J. Griffin, Society of Chemical Industry, 14 Belgrave square, London, S.W.1

12–14 Philadelphia
International Symposium on Agglomeration
Metallurgical Society of the AIME, 29 West 39th Street, New York 18, N.Y.

16–18 Houston, Texas
7th Annual Instrumental Methods of Analysis Symposium and Exhibit
The Executive Director, Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22, Pennsylvania

17–20 Bristol, England
Annual Conference of the Ergonomics Research Society
O. G. Edholm, Medical Research Council, Hampstead, London, N.W.3

20–21 Reading
Meeting on Theoretical Rheology
Dr M. F. Culpin, British Society of Rheology, 8 The Broadway, Pontypool, Monmouthshire.

20–May 4 London
Engineering, Marine, Welding and Nuclear Energy Exhibition
F. W. Bridges & Sons Ltd, Grand Buildings, Trafalgar Square, London, W.C.2

MAY

7 Ghent
13th International Symposium on Crop Protection
Prof. Ing. J. Van den Brande, Institut Agronomique de l'Etat, Coupure Gauche 233, Ghent, Belgium

SCIENCE ON THE SCREEN

National Film Archive: Catalogue Part II Silent Non-Fiction Films 1895–1935

(*The British Film Institute, London, 1960, x+195 pp.*)

This second part of the Catalogue of the National Film Archive follows nine years after the first (devoted to Silent News Films, 1895–1933) and the third part will, in turn, deal with silent fiction films.

In a brief "Foreword" Sir Arthur Elton vividly describes the difficulties of collecting early films and the even greater difficulties involved in cataloguing films when acquired. These difficulties are particularly great when much of the collection is film material without title; here skilled detective work is necessary to trace its origins. In an even briefer "Introduction", the Curator, Mr Ernest Lindgren, outlines the steps involved in cataloguing a film. He points out that the Archive's Catalogue (of which this is one part) is believed to be "a unique pioneer effort in the field of film cataloguing"; as such it sets a high standard. Each entry has a title, even if one has had to be invented for an untitled length of film, a catalogue number, any "credits" as are available, a synopsis of the contents, the footage, and finally references to any published account of the film. All this information has been assembled with great skill by the Chief Cataloguer, Mr David Grenfell, and his staff, who are to be congratulated on the outcome of their work.

A review of a catalogue must of necessity be somewhat different from a review of a book. Since it is impossible to state the scope of a very heterogeneous list, all that can be done is to give an idea of what sort of inquirer might find this list useful. Suppose you are interested in the history of film itself, under "France" you will find the names of E. J. Marey, Louis Lumière, Jean Comandon, and Lucien Bull; the Société Lumière is represented by examples from 1896 onwards and Pathé Frères from the same year. The list for Great Britain includes the names of Friese-Greene and of many of the early production companies (for example, Warwick Trading Company, Hepworth Manufacturing Company). The list for Great Britain is appropriately long and readers of this journal will probably be interested in the scientific entries such as Percy Smith's *The Birth of a Flower* (time-lapse cinematography) of 1911, several films of bees by J. C. Bee-Mason, Frank Hurley's record of the Shackleton Expedition and H. G. Ponting's record of the Scott Expedition (although the copy in the Archive is the 1924 reissue and not the original, which some of us remember Ponting talking about at the old Philharmonic Hall).

However, you may be interested in other subjects and give your attention to Medicine, Travel, the History of Costume or of Dancing (ballet, ballroom, national), all these and many more are listed in a detailed and accurately cross-referenced subject index, the last five entries under "F" reading, Friese-Greene, Frogs, Fruit cultivation, Funeral ceremonies, and Funfairs.

At first it is difficult to think of subjects which have not at least one film, like Celery trenching, Census taking, Centipedes, and Ceramics.

However, a little reflection shows that, despite the fact that it was Marey's interest in the analysis of animal locomotion that led to the cinematograph camera being perfected when it was, science as a whole and scientists in particular are not well represented. I receive the impression that early film makers in all countries concentrated on dramatic events, such as the turn-out of a fire-engine; another favourite subject was the countryside as seen from moving trains. Science was treated in a superficial manner and many "nature" films were made. There seem to be very few films of experiments, *The Electrolysis of Metals* (1913), *Making Steel: Martin-Siemens Process* (1914), are two of a few with titles which at least suggest the scientific film of more recent years.

Scientists are even more difficult to detect. Sporting personalities are much more frequent; Hobbs and Sandham, Mlle Lenglen and Miss Betty Nuttall. Aviators, Explorers, Politicians, and Statesmen are all to be found although the news-reel material is not covered by this catalogue. In fact I have not detected the name of a "pure scientist" who appears in any of the films; the nearest are the first and second Lords Melchett and Lord McGowan who appear in *The Construction of Imperial Chemical House, Part 4* (1928). Clearly, in the silent days film was not a medium of scientific recording or instruction and it hardly seems to have been a respectable medium in which to be seen! It is to be hoped that some great scientists, perhaps receiving honorary degrees, have been preserved in the news-reels; others who lived on into the sound era are known to have recorded lectures, but there are obviously gaps which cannot now be filled *unless* more films of the silent era come to light. It is greatly to be hoped that this Catalogue will make the existence of the National Film Archive more widely known than it seems to be and that owners of old films, whatever the subject, will offer them to the Archive for expert appraisal before the film deteriorates beyond repair. Early film was very unstable and little of that of the silent era is in good condition. If any more is to be saved there is very little time in which to do it. Once in the Archive, the film is stored under the best conditions and, if it is found to be deteriorating, copied; this is common knowledge. What is also now clear is that not only is film preserved with skill but that it is catalogued and documented in a manner befitting to a National Collection. It is a great pity that the financial stringency which afflicts all National Collections should have necessitated an interval of nine years between parts one and two of the Catalogue; it is to be hoped that we do not have to wait another nine years for the third part.

G. E. H. FOXON

Hospital Sepsis—A Communicable Disease

16 mm. Sound. Colour. Running time 28 minutes. Produced under the direction of Dr Carl Walter of the Harvard Medical School in collaboration with the American College of Surgeons, with the sponsorship of Johnson and Johnson. The film, wall charts, and discussion notes are available on free loan to hospitals, medical organisations, and other interested bodies. All inquiries should be made to Myles A. Adburgham, Johnson and Johnson (Great Britain) Ltd, Slough, Bucks. Tel.: Slough 25521.

Cross infection within hospitals has been a problem for hundreds of years. Pioneers like Pasteur showed that micro-organisms are responsible for infection. Joseph Lister introduced antiseptics and stressed the importance of aseptic conditions in surgery.

This need for cleanliness is realised by medical and hospital authorities but it is difficult to convince hospital workers at all levels of the dangers involved. This film is directed to such hospital workers, and although it was made in America, it is just as valid in its message in any

country in the world. The sponsors have brought over the film without any alteration; in its use, down to ward orderly level, its impact is unimpaired, providing that it is suitably introduced by a doctor or trained nurse, and providing it is followed by discussion.

Mrs A suffered from boils due to staphylococci. The film records and studies how bacteria spread from what is apparently a completely aseptic room. Sweeping, walking, talking, transporting laundry, and going to the bathroom all send out waves of potentially dangerous bacteria. In fact, no aspect of human life seems to be without inherent danger. It makes one wonder how everyday life can be survived.

The film then shows how every member of the staff can play his part in avoiding the spread of hospital sepsis. Microphotography and diagrams are used to show how bacteria can incubate.

The general impact of the film is good. The only thing to be regretted is that the diagrams are inclined to be too arty for the rank and file. The waves of bacteria going out are shown in an attractive primrose yellow which suggests wealth and beauty rather than danger. It is important that the factors which psychologists have discovered about the emotional and intellectual impact of colour should be considered by film makers when designing relatively abstract symbols in technical and scientific films. L. GOULD-MARKS

This Year, Next Year, Sometime

16 mm. Sound. Colour. Running time approximately 15 minutes. Produced, written and directed by Richard Taylor for the Marlborough Hospital, St John's Wood, London, N.W.

This film was made for £60 in cheque book money—the cost in effort and spare time activity by the volunteer film makers, cannot be estimated in actual cash. It was made to show the work of a day nursery for psychotic children. These children who are abnormal rather than sub-normal can make little, if any, contact with the outside world. The film shows simply, warmly, humanly, how patience and simple loving kindness combined with a profound knowledge of psychiatry and psychology can possibly bring them into closer contact with reality.

One or two case histories are presented, not at all scientifically, but just as human documents showing how some children progress, and others remain the same. One little girl rocks endlessly on a rocking horse. It is sad, but it is important. This film for lay audiences shows a very real, and all too common, problem.

This excellent film was made in three mornings, by the Director during time off from his regular job as a BBC television editor. What it really needed was to be made over a long period of time, so that we could see how the children progressed, or remained the same, under treatment. Nevertheless, many very expensive documentaries have not the sensitiveness of photography, editing, commentary, and music that this film has. It emerges as an integrated work of art telling an important story.

L. GOULD-MARKS

The Information Machine

16 mm. Sound. Colour. Running time 10 minutes. Written and directed by Charles and Reg Eames, music by Elmer Bernstein. (*Available on free loan from Public Relations Department, IBM, Wigmore Street, London, W.1.*)

The Brothers Eames, American designers, produced that great but controversial film on human communications—*Communications Primer*. Your reviewer would like to remind readers that, if they have not seen this film, with its exciting music, its visual treatment reminiscent of Picasso, and its direct scientific message on the meaning of communication, they should try to see it at the earliest opportunity. (*Available from GB Film Library, Perivale, Middlesex*)

Their new film is imaginative and exciting. It sets out to be a simple but not over-simplified explanation of data processing on electronic computers. It begins with early man and the story of the three wishes. In most fairy tales the first two wishes have been so haphazard, that the third wish is needed to put things right.

The human mind stores information but sometimes has some difficulty in sorting it out. Now computers have been developed which can store, process, and relate information. They can be used for control, for design, and for simulating life. This information machine can turn information into fruitful and profitable action.

That is the theme. The Eames brothers have obviously studied it, tossed it around, and come up with some brilliantly clever ideas. These make it a challenging and stimulating film. Whether it can be considered as a simple explanation of data processing is another matter. A film which is so imaginative, so full of exciting images and clever music may well charm one away from its main message. This is what happened to your reviewer. He was completely fascinated. He loved every moment of the film, but he knew very little more about data processing after he had seen it. This is a sad, an awful warning. Sometimes the clever side-effects are so overwhelming, the main part is lost. See the film if you can, it is a worthwhile experience, but you will have to watch and listen very carefully if you want to learn much about data processing from it.

L. GOULD-MARKS

More than Words

16 mm. Sound. Colour. Running time 13 minutes. Produced by Henry Strauss and Co., Inc., New York. (*Available from GB Film Library, 1 Aintree Road, Perivale, Greenford, Middlesex. Perivale 7481. The hire rate is £2 per day; purchase price £32 10s. 0d. Catalogue No. IFC7303.*)

In this film we never see a face, we see hands, legs, tapping fingers, executive cigars, typewriters, and telephones. The rest of the film is visualised in mobile, constantly changing, coloured line drawings. Yet it gets over its message with a directness and economy that is outstanding. The commentary is American, but little translation is necessary.

It is another film on communication from the same intellectual stable as *Production 5118* and *Communications Primer* (both of which are available from the GB Film Library). It is simpler and less controversial than either of these other films on that part of human communication which takes place in working hours.

So many ideas, orders, instructions, and just plain remarks fail to get across. They fail because the speaker, the writer, or the telephone correspondent, does not consider the psychological receptivity of his audience. Too often we boost the bumptious and snub the difficult. This film tries to show that emotions are almost as important and in certain cases more important than intellectual comprehension. It is a well worded plea for more common sense and less self-conceit when we try to communicate with our subordinates and our superiors.

After seeing it for the first time your reviewer incorporated it in a presentation he was making to a group from twenty countries, including Arabs, Indians, West Indians, French, and Dutch. Every single member of the group, whatever his national background and personal frame of reference, seemed to be convinced that better communication is an absolute necessity. Unfortunately, putting over ideas is not yet an exact science, but if this film can do anything to improve the ways in which we use the five senses in communicating fact and theory, it will serve a most useful purpose.

L. GOULD-MARKS

LETTERS TO THE EDITOR

Patterns of Swearing

Sir:

I was the leader of the Oxford Finmark Expedition, and I read Miss Ross's dissection of our swearing habits with amusement and interest; I feel that this is an interesting approach to the study of human behaviour. It is a curious reversal of roles for an ethologist to become an experimental animal; from my experience in both capacities I would like to comment on Miss Ross's article.

Miss Ross's hypothesis is that, with increasing stress, "social" swearing declines, and "annoyance" swearing first increases and then falls off. I am not sure that she has entirely proved her point.

1. Miss Ross has not really justified the decline on "social" and increase in "annoyance" swearing during medium-stress situations. How are the two types to be distinguished? Perhaps the best way to do this would be to study an individual in situations of extreme relaxation and anxiety, and note differences in tone of voice, words used, etc., in these contexts. One could then apply these differences to intermediate situations and plot more exactly the changes in the two types of swearing.

2. It is certainly true that under conditions of extreme stress there is a fall-off in the swearing rate—but this is also true of the speech-rate in general. My own impressions are that under extreme stress one uses very few words, but that most of them are swear-words. To demonstrate a final fall-off one would have to use, not an absolute swearing rate scale, but one based on the relative proportion of swear-words in general speech.

Finally, I feel that the motivation problem may be more complex than Miss Ross outlines. I agree that swearing may be an indication of extraversion. But in our group I would have said that the heaviest swearer was not really an extravert, but rather an introvert trying to appear an extravert. R. G. B. BROWN

Department of Zoology and Comparative Anatomy, Oxford

Sir:

Mr Brown has raised some points which are interesting, but not, I think, crucial to my hypothesis.

It would certainly be useful if we could find some objective way of distinguishing between "social" and "annoyance" swearing, but in practice we have to rely upon a combination of the ones he suggested. We are usually fairly successful at this, perhaps because there is some survival value in the ability to recognise quickly whether other people are in a hostile or friendly mood.

It is possible that the drop in swearing under heavy stress is merely a result of the drop in the general speech-rate, but I suspect that the latter is partly due to physical tiredness and that there are many occasions when one talks volubly about anything irrelevant but will not complain or swear about the matter that is really troubling one.

As for the correlation of swearing with extraversion, one obviously needs a larger sample than eight people before drawing any definite conclusions. H. E. ROSS

Oxford

Science in China

Sir:

The public has indeed much reason to be grateful for your excellent article, "China's Forward Leap in Science".

May I be permitted to remark, however, that the distinguished author is not quite correct in his statement that the Chinese Academy of Sciences was named "Academia Sinica" by the Chinese Communists in the course of their reforms after they came into power.

While it is quite right to say that a merger of two academies took place, the "Academia Sinica" had already been in existence many years in 1949, since it was founded by the Kuomintang. In essence, your author is right, because it could be regarded as a product of the collaboration between the Kuomintang and the Komintera in the twenties.

It is stated in the article that, in 1957, China had 227 institutions of higher learning. Your readers may care to note that, according to the Chinese Press, the number of these was expanded in the course of the year 1958 to 1065, and that on August 1, 1958, the first intake of 50,000 students entered the Communist Labour University in Kiangsi. It seems also that the ultimate intended student population of this latter body composed of a group of colleges will be of the order of 400,000. It is of interest to note that one out of a thousand higher educational establishments in this vast and dynamic country is intending to accommodate rather more than twice the entire university student population of this country. The long-term consequences of this will be grave and we should take heed. A. H. S. CANDLIN

Northampton College of Advanced Technology, London

Science Teaching

Sir:

Recently the Minister of Education has taken far-reaching decisions concerning the future pattern of teacher training in this country. Implicit within these decisions appear to be certain threats to the future of science teaching in the schools.

At present, science and mathematics teachers—whether graduate or non-graduate—are in short supply. In general, the graduate recruits find posts in the grammar schools and the non-graduate in the modern schools. In the future we can expect this pattern to be maintained with the one important modification that the students from the training colleges will have spent three years in colleges selected because they are adequately equipped and staffed to train specialist teachers of science.

On the other hand, the new teachers of the other academic subjects in these schools are to be recruited from the vastly expanded output of the arts faculties of the universities—from men and women who may well be entering the teaching profession in default of any other outlet. The result must be a division of the staffs of the secondary modern schools into two groups: on the one hand, graduate arts teachers; on the other, non-graduate science, mathematics, handicraft and physical education teachers. So the teachers of science will be lower paid and apparently of lower status than, say, their colleagues who teach history or geography. This can only lead to a lower regard for science in the eyes of the public and must make recruitment into science teaching an even less attractive proposition than it is at present.

Recognising the vital need for better science teaching in all schools, one cannot but regret that this change should be contemplated, and it is profoundly to be hoped that some modification to the present policy of the Minister can be secured. Perhaps the solution lies in the introduction of a four-year training college course for science specialists (and their mathematics, handicraft, and P.E. colleagues) which would lead to a degree in Education and the specialist study, or perhaps in a new pattern of training in

which students spending three years studying science and science teaching in the training colleges complete a degree in science by spending a fourth year at a university. E. J. WENHAM

Senior Lecturer in Physics,
City of Worcester Training College

Science versus Babel

Sir:

Mr Jackson's riposte to my letter is not on a par with his workmanlike article. He says that it is no use interlinguists claiming that their particular auxiliary language is better than someone else's. But how else can such an idea be sold to the potential consumers, in this case scientists?

Concerning the "vicious circle" which he claims dogs such inventions: insufficient published in the language, therefore lack of interest, therefore insufficient published, etc . . .; this is precisely what proponents of Interlingua do *not* complain of, with a semi-official agency in the U.S. (Science Service) printing a regular abstract of its magazine, with the "Journal of the American Medical Association" using Interlingua every month, and with an average of one international medical conference every year admitting it to the status of one of the official languages for resolutions and summaries of papers.

The latest of such conferences was the International Conference on Endocrinology, which took place between July 18 and 23, 1960, in the state Technical High School in Copenhagen.

The characteristic of Interlingua which should enlist Mr Jackson's support, and that of your readers, is that it is the first auxiliary language, out of the hundreds that have been proposed, to attain any considerable circulation among *non-linguists.* I know that you will probably have letters challenging this statement, but I can furnish evidence on the point. R. SPATHAKY

Assistant Editor,
"Le Currero International".

Sir:

Probably nearly 100% of the persons who read and make use of the abstracts and reports published in Interlingua have at no time studied it as a language. This sort of use is the *raison d'être* of Interlingua, enabling it to break out of that vicious circle which, as Mr Jackson has so well perceived, condemns the "closed" type of artificial interlanguage to inevitable sterility. B. C. SEXTON

Secretary,
British Interlingua Society,
Birmingham.

THE PROGRESS OF SCIENCE

(continued from page 3)

NEW ATMOSPHERIC RESEARCH CENTRE IN U.S.

A National Centre for Atmospheric Research is about to be established by the United States on Table Mountain, near Boulder, Colorado. This site has been selected because it is centrally situated with respect to research establishments and other organisations, and because of the advantages it offers for the study of particular atmospheric phenomena. Its location is considered highly desirable for the study of hail, thunderstorms, tornadoes, and associate squall line phenomena. The site is also well suited for the study of jet streams and the weather in the belt of maximum westerlies.

The mountainous areas near by produce local effects that may materially affect weather conditions throughout the Great Plains and even beyond, some of these effects extending to heights of 80,000 to 100,000 feet. The location is also suitable for the observation of high ionospheric layers and atmospheric airglow.

As the programme of the Centre matures, it is expected to encompass fundamental studies of the global weather system, including such things as the association between circulation in the northern and southern hemispheres on a year-to-year time scale, the development of planetary wave systems that affect the meanderings of the jet streams, and the radiative effects of the global cloud cover.

Since one single location will not enable the study of all types of weather phenomena, field stations and supplementary research facilities are expected to be added later.

According to its Director, Dr W. O. Roberts, "the Centre will be primarily an intellectual enterprise devoted to fundamental research on broad atmospheric problems. It will serve as a co-ordinating centre for a wide-ranging network of such investigations. This effort can be expected to develop a much more comprehensive understanding of weather and other phenomena than has ever been possible through isolated research."

The Centre will be managed for the National Science Foundation, a Government agency, by the University Corporation for Atmospheric Research, a private organisation composed of representatives of fourteen colleges and universities with degree-granting programmes in meteorology.

IMPROVED CANCER DIAGNOSIS CLAIMED FOR NEW X-RAY TECHNIQUE

An x-ray test that is better than 99% accurate in spotting early, even unsuspected breast cancer is being claimed by Dr R. L. Egan of the M. D. Anderson Hospital in Houston, Texas. Dr Egan contends that the use of soft x-rays permits far more accurate differentiation between benign and malignant tissues than the conventional use of x-rays and that lesions as small as 8 mm. have been picked up with low-energy beams.

In an interview with *Medical News,* the Houston doctor said his method was extremely simple and required no special equipment. It called only for the employment of relatively fine grain Type M industrial x-ray film and beams in the 26–28 kilovolt range. This combination was said to sharpen the inherent contrast between various benign and malignant breast tissues.

So far, low-energy röntgenograms have been obtained with 4000 women who were referred because of a variety of mammary or axillary symptoms. Follow-up of the first 1000 who were x-rayed between 1956 and 1959 confirmed 245 cases of cancer; only two were missed and Dr Egan states that these were in the axillary and sternal areas which had not been designated for inclusion in the x-ray field. Of paramount significance was the fact that nineteen of the cases had not been apparent clinically and were totally unsuspected. The second set of 1000 röntgenograms appears to be yielding the same high diagnostic accuracy, although it has not been fully evaluated as yet.

According to Dr Egan, a diagnostician must become thoroughly familiar with the appearance of benign and malignant lesions in low-energy x-ray pictures in order to differentiate between them. Recognition of malignancy rests primarily on characteristics of the x-ray shadow, fine calcifications, and changes in the fibrous septa. Since the low beam intensity reduces the radiation hazard, this technique may hold promise for screening tests.

500,000 GALLONS OF SALT-FREE WATER PER DAY FOR GUERNSEY

A 500,000 gallon-per-day desalination plant has just gone into operation at Guernsey, one of the Channel Islands, to supplement the supply of fresh water obtained from reservoirs and catchment

areas for the £7·5 million tomato- and flower-growing industry. Although this is one of the largest units in operation at the present time, its builder, G. & J. Weir of Glasgow, has already constructed a plant with a capacity of 1 million gallons per day.

The operating cost of the distillation unit at Guernsey is approximately 7*s.* per 1000 gallons. The capital charges for the £257,000 plant, based on a 20-year life, will raise the cost of 1000 gallons to 16·5*s.* but Weir states this is still only half the cost of a storage system. Weir contends it can usually reduce this figure to 4*s.* by combining the distillation process with the generation of electric power.

The Guernsey unit contains an evaporator 69 ft. long, 19ft. wide, and 18 ft. high that is subdivided into a number of flash and pre-heater chambers. The incoming sea water passes through heat exchangers in the forty flash chambers and is then heated further by the exhaust steam from a steam engine. After this it passes into the flash chambers themselves, flashing off salt-free vapour which is then condensed in the heat exchangers by the incoming water and pumped to storage. A partial vacuum is maintained in the flash chambers by means of an air ejector to reduce the amount of heating required. De-aeration of the incoming sea water and chemical injection equipment are employed to keep corrosion and scale formation to a minimum.

NEW SERIES OF MONOGRAPHS ON RADIOCHEMISTRY

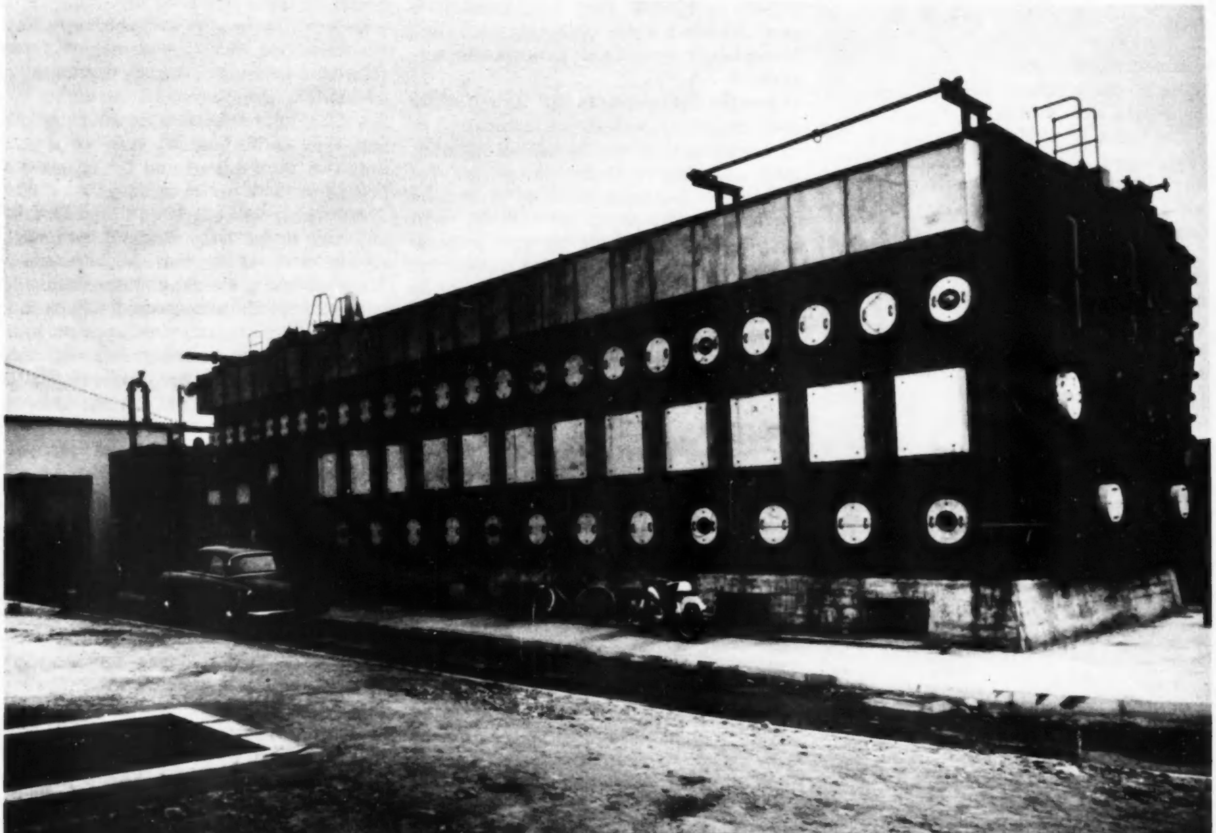
Preparation of fifty-six monographs on the radiochemistry of the elements is being carried out in the United States under the sponsorship of the National Academy of Sciences—National Research Council and the Atomic Energy Commission. Thirteen have already been published covering cadmium, arsenic, francium, thorium, fluorine-chlorine-bromine-iodine, americium-curium, chromium, rhodium, molybdenum, barium-calcium-strontium, zirconium-hafnium, astatine, and indium. The remainder are expected to be out during the coming year.

Each monograph is, or is to be, an up-to-date compilation of the latest radiochemical information and procedures, written by an authority. The series was designed to be of interest not only to radiochemists but also to geochemists, nuclear physicists, biochemists, nuclear engineers, and those working in medicine, environmental health, fall-out analysis, activation analysis, and so on.

THE WELL-FED IRISH

The average Irishman, if there is such a thing, has a larger food intake by calories per year than anyone else in the world, according to statistics interpreted by the Food and Agricultural Organisation. An average of 3500 calories per head per day are available to the Irishman, as against 3430 calories to the New Zealander (second largest eater), 3350 to the Dane, and 3260 to the Englishman. The Australians average 3200, the Swiss 3180, and the Canadians 3110; **3100 is typical in**

The newly installed half-million gallon per day desalting unit at Guernsey.



both the United States and Argentina. Statistics are not available from the U.S.S.R., Communist China, and a number of under-developed countries.

A closer examination shows that cereals are the largest single calorie supplier in all the national diets. Next on the Irish list are milk, fats, and oils, in that order. In New Zealand, meat is the second largest supplier of calories. In Denmark, surprisingly, milk falls at the bottom of the list.

The FAO figures on net food supply per head have been calculated by adjusting national food productions for in and out trade, stock changes, animal food, seed and non-food purposes, the whole being divided by population estimates. It is far from clear what validity such figures have since there are such wide extremes in a country like Ireland. But it is perhaps better to have these figures than none at all.

MORTALITY DROPS AND SHIFTS IN EUROPE

During the 1947–57 decade in Europe, general mortality decreased 9·6%, infant mortality fell 43% and deaths from tuberculosis dropped by 72·6%, according to a World Health Organisation analysis of fifteen European countries west of the Iron Curtain.

Although the number of deaths from communicable diseases in Europe has gone down markedly, there has been an increase in the deaths from cancer, mental illness, and cardiovascular diseases, however. But it is a misnomer to call these "diseases of civilisation", Dr J. J. van de Calseyde, Director of the WHO Regional Office in Europe, points out. More are now dying from these ailments because fewer are victims of communicable diseases. The average life-span has increased from 50 to 70 years and it is during the 50- to 70-year period that cancer and cardiovascular disease have always taken their heaviest toll. He attributes the increase in mental illness to the movement of country people to the towns, where they are exposed to stresses they are not always capable of sustaining.

THE LAG IN THE MACHINE-TOOL INDUSTRY

Although two recent reports criticising the British machine-tool industry have remained unpublished, their nature has become widely known. One is Prof. Melman's controversial report to the European Productivity Agency on the machine-tool industry of Western Europe; the other is a DSIR study.

To counter the effects of these reports, the Board of Trade recently made public a third one by the "Mitchell Committee"—a sub-committee of the Machine Tool Advisory Council that was made up of representatives of the industry itself, user industries, the Trade Union Congress, and the Board of Trade. This sub-committee was appointed to consider the British aspects of the Melman report and ended up by rejecting its main recommendation—that the mass production of machine tools be introduced rapidly into the industry of Western Europe. The very essence of mass production, the sub-committee stated, implies standardisation of the product with a high and stable demand. Even if this could be achieved, the demand for any one type of machine would still be too low to justify mass-production methods, they added.

The conclusions Prof. Melman reached from developments in the Soviet Union were also questioned, for the Russians have been able to apply mass-production methods to only a small sector of machine-tool production. The greater part of the output from the Soviet Union comes from production methods similar to those used in the West.

The real threat from the East seems far more likely to arise from two other causes: (*a*) the ability of the Communist bloc to sell at prices which do not reflect the actual costs of production, a factor Britain can do very little about, and (*b*) tangible signs of an impressive research and development effort in the Soviet machine-tool industry which must inevitably be reflected in the excellence and competitiveness of their products.

The Mitchell Committee sees in the latter a major challenge to British industry and offers some significant findings of its own. It spotlights a shortage of skilled personnel as the main defect—one cause of the industry's unresponsiveness to changes in demand and the resultant over-concentration on the production of some standard lines. This is also given as a reason for the industry's inability to mount a sufficient development effort. The sub-committee reviews steps to remedy this situation, including the placing of development contracts by DSIR and the establishment by the industry of a co-operative research association linked, if possible, to a teaching centre. It adds its own recommendation that the industry's annual research outlay be raised from £3 million to £8 million (about 10% of the turnover) by 1963, emphasising that this will require a sizeable increase in the number of scientific and engineering graduates employed.

In 1958, 90 machine-tool firms employed a total of only 25 graduate engineers; at the present time, only 120 qualified individuals are in research and development. This number will have to be expanded by an additional 250 to 300 persons if the desired results are to be achieved, the sub-committee pointed out.

WHITHER THE TRANSPORT SYSTEM?

The British Transport Commission is spending £2 million a year on scientific research to make travel more agreeable and reduce running-costs and maintenance. Studies involving the permanent way are claiming particular priority because diesel and electric locomotives now replacing the steam engines are creating unknown stresses in the track with their smaller wheels. There are also dynamic problems involved in the "riding" of vehicles; since the former railway companies failed to find a design of bogey suitable for stable riding at high speed and under modern conditions, a long-range research project has been placed with University College, London.

Also under study are ways of minimising breakdowns of diesel locomotives, since they involve a much higher capital investment than the steam engines they are replacing. There is also the possibility of cutting costs of electrification in half by going from the present 1500 volt D.C. power supply to the 25 kV A.C. grid. This step would lower capital costs and increase reliability by permitting the use of simpler types of motors. Operational research and computer studies are in progress to ensure the more efficient use of a smaller fleet of rolling stock. In London, research is being done on fuel consumption and air pollution, the icing

of the conductor rails of the underground system, and the traffic congestion problem.

The structure of the British Transport Commission and the fate of the railway modernisation programme have been under active study by the Minister of Transport; some of his conclusions have just been published. This latest study appears to be an attempt to break up the centralised structure of the BTC. Many experts contend that if this is done, the public transport system will deteriorate further. One of the unknown questions is the fate of the research programme now being carried on for the entire system. If the Commission is broken up, the research programme may also be fragmented. Before the transport system was nationalised, scientific activity in this area was negligible. Today, with the transport problem more severe than ever, less than 0·3% of the Commission's annual turnover of £730 million is devoted to research and development.

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